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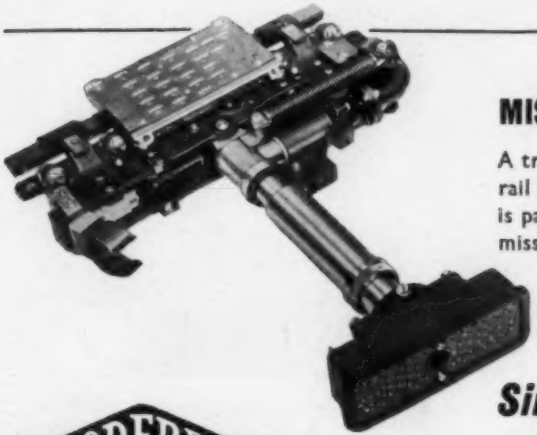

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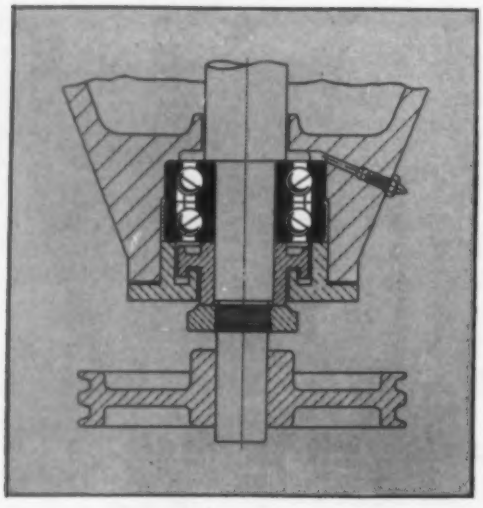

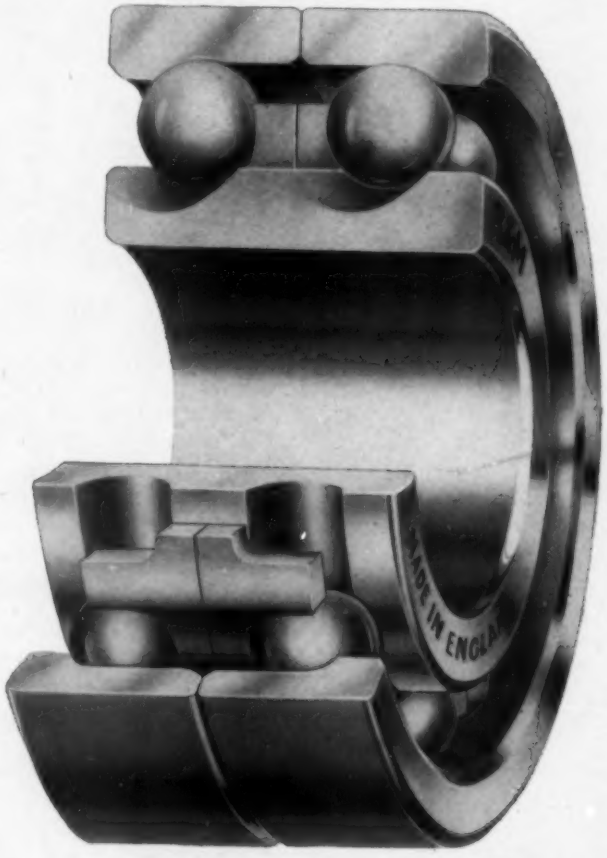

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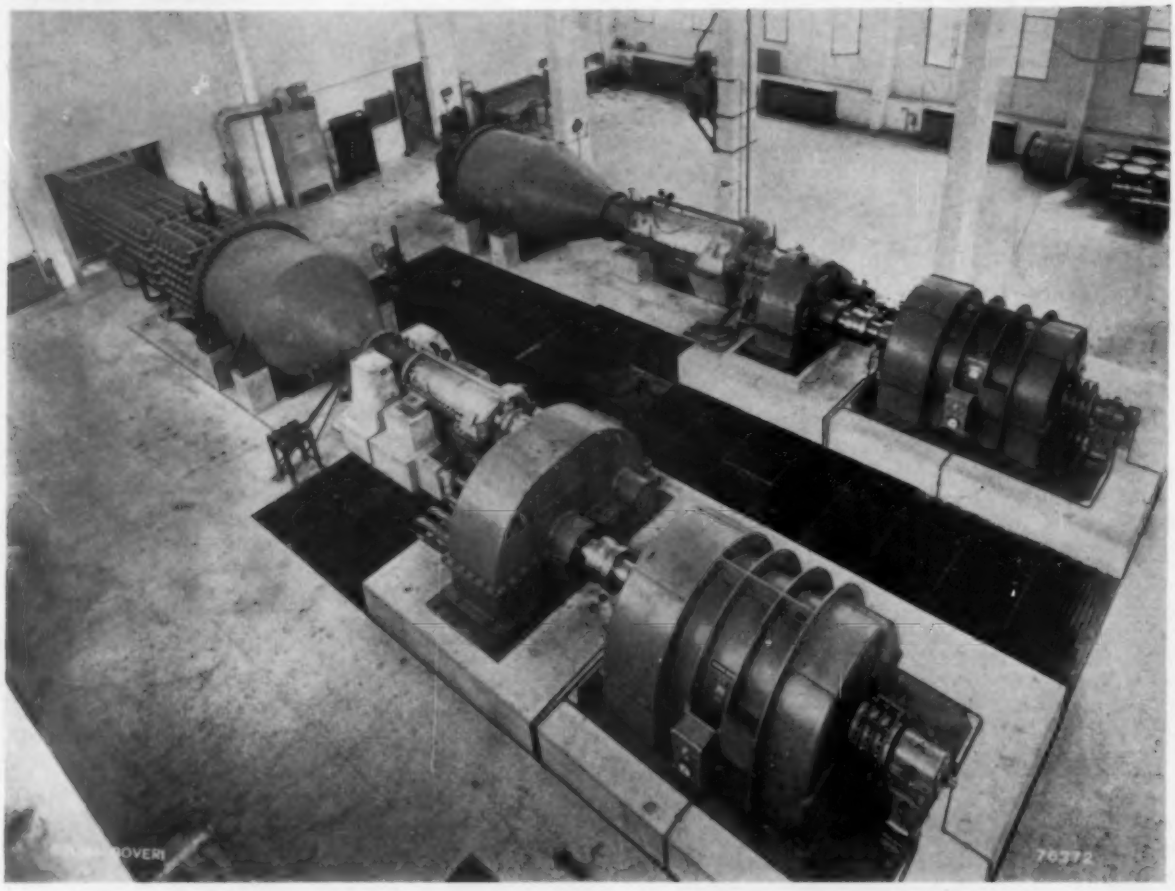

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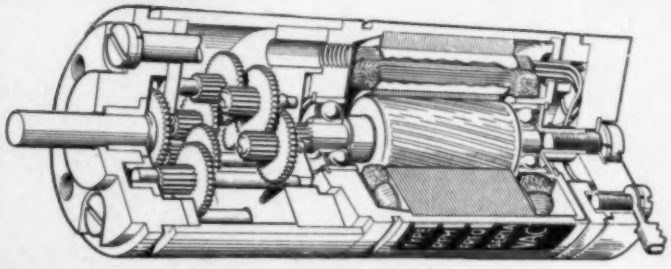

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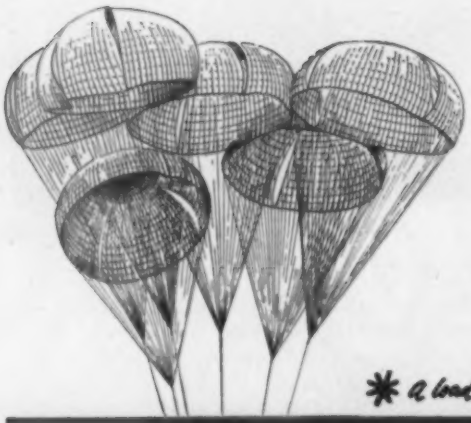

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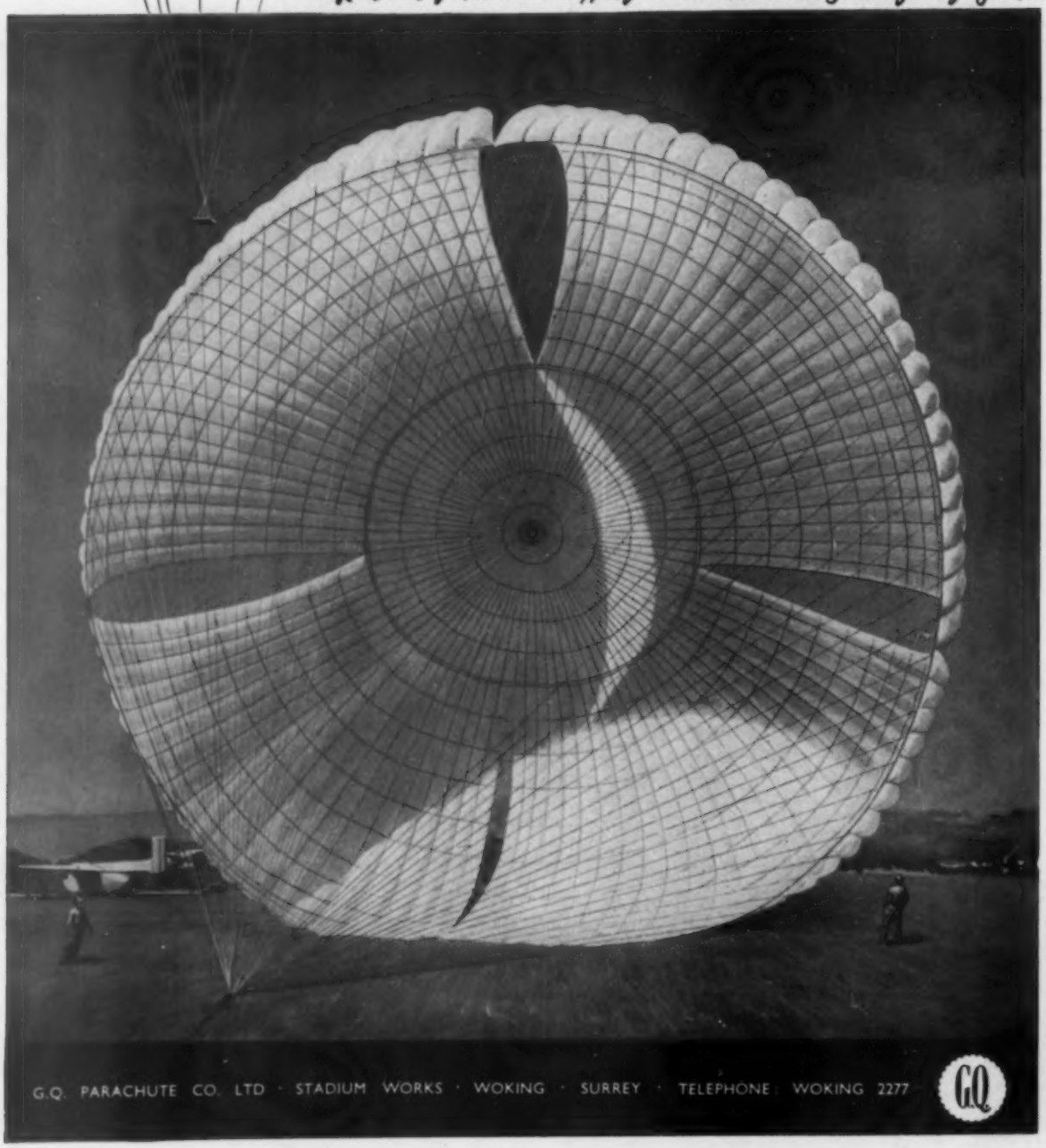

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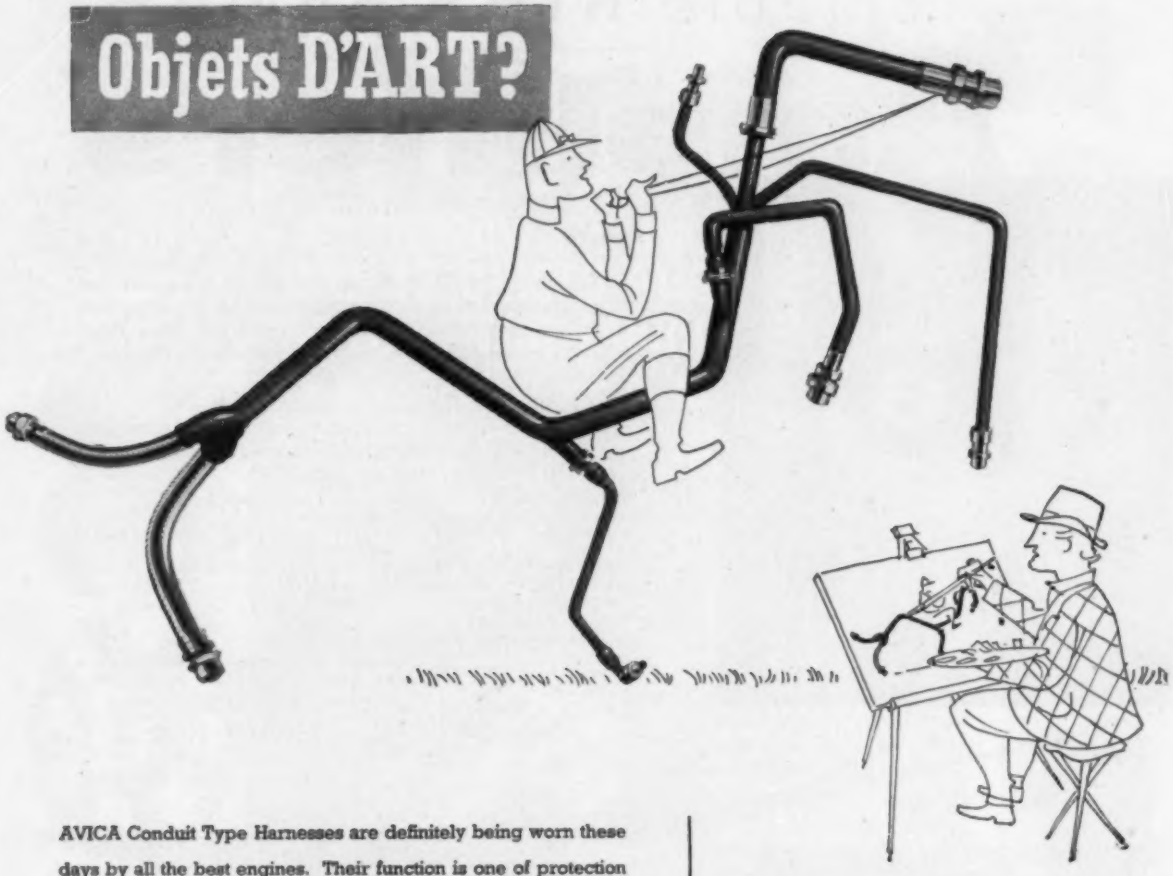

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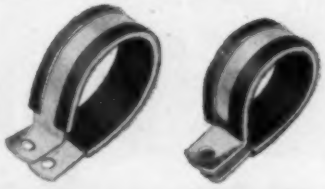

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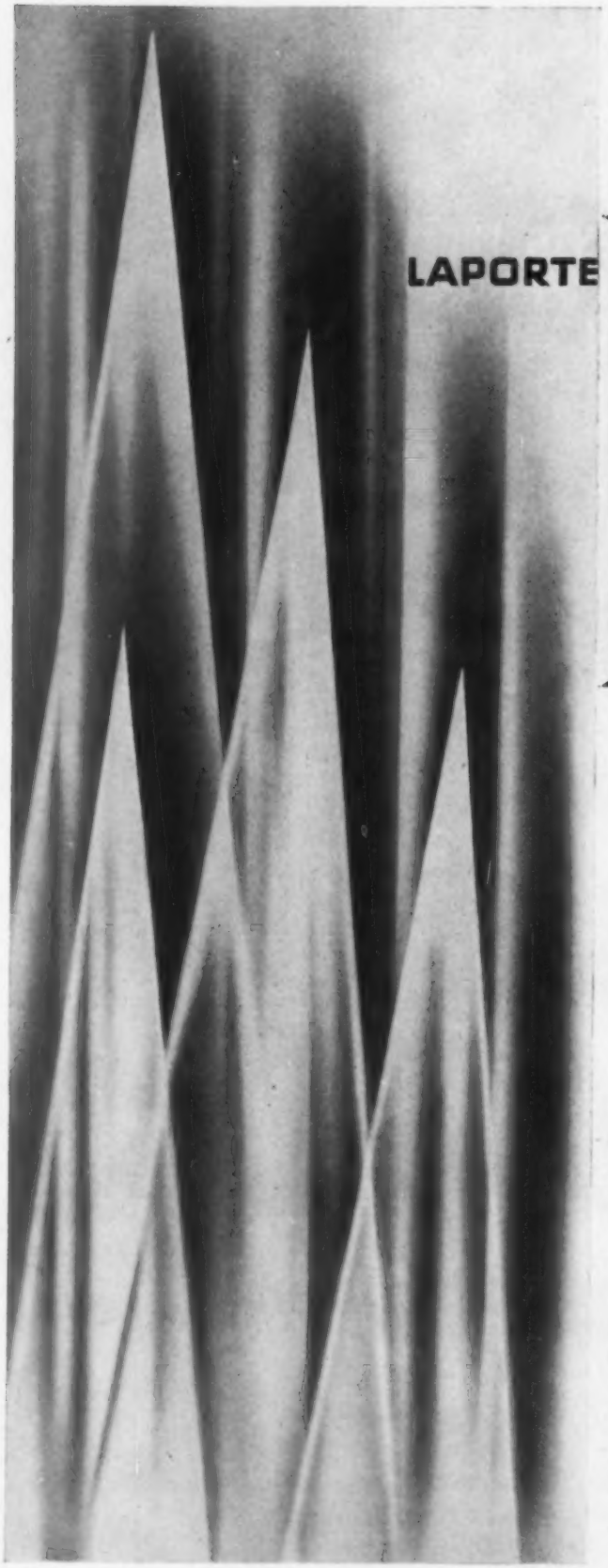

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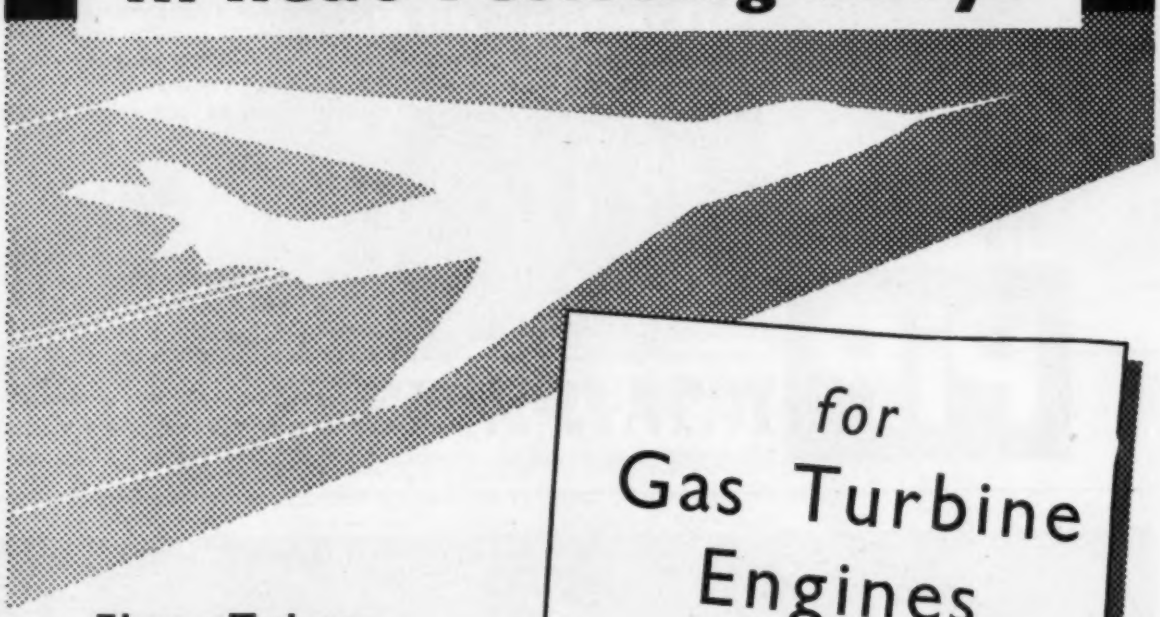

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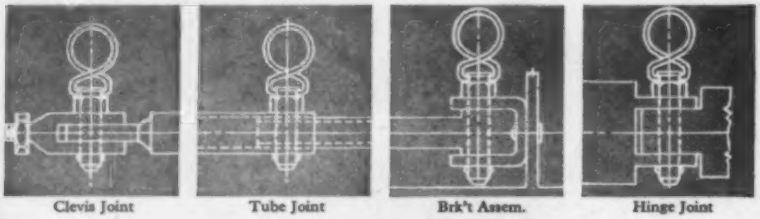

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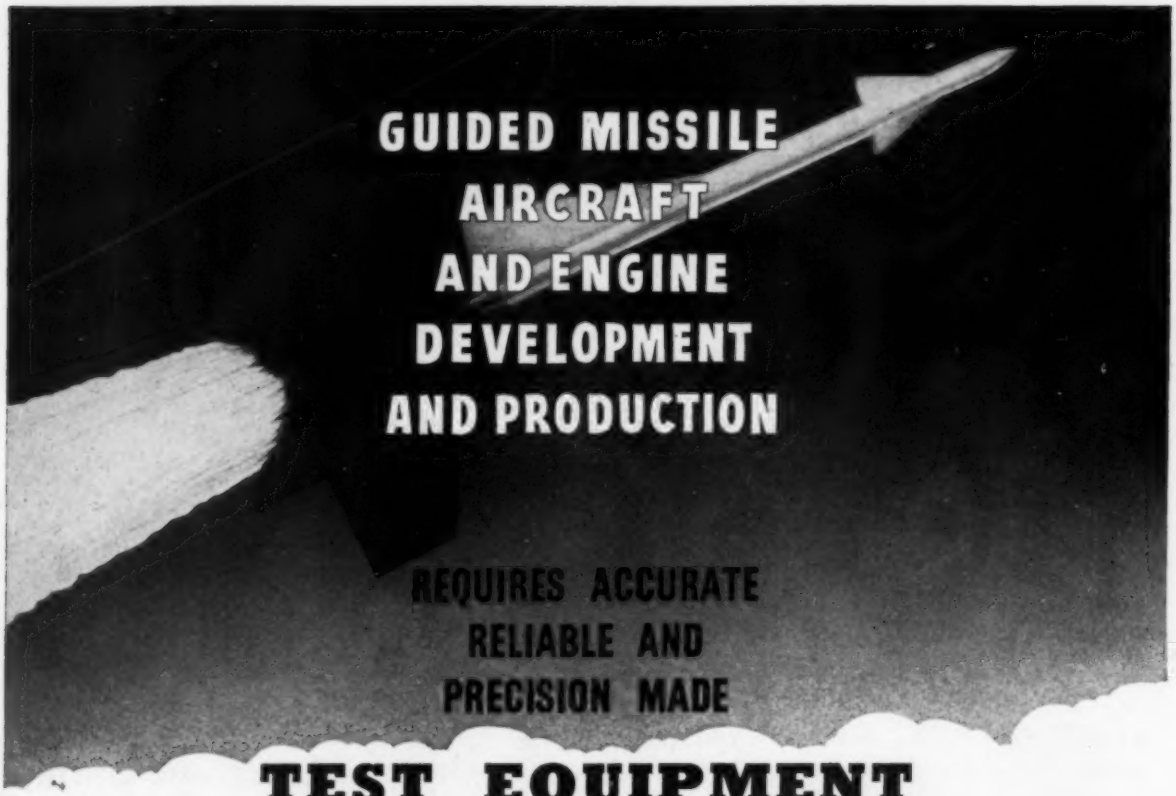

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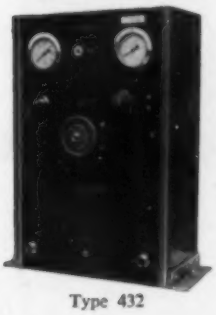

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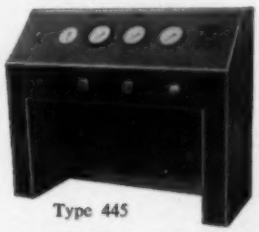

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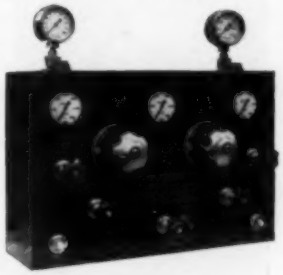

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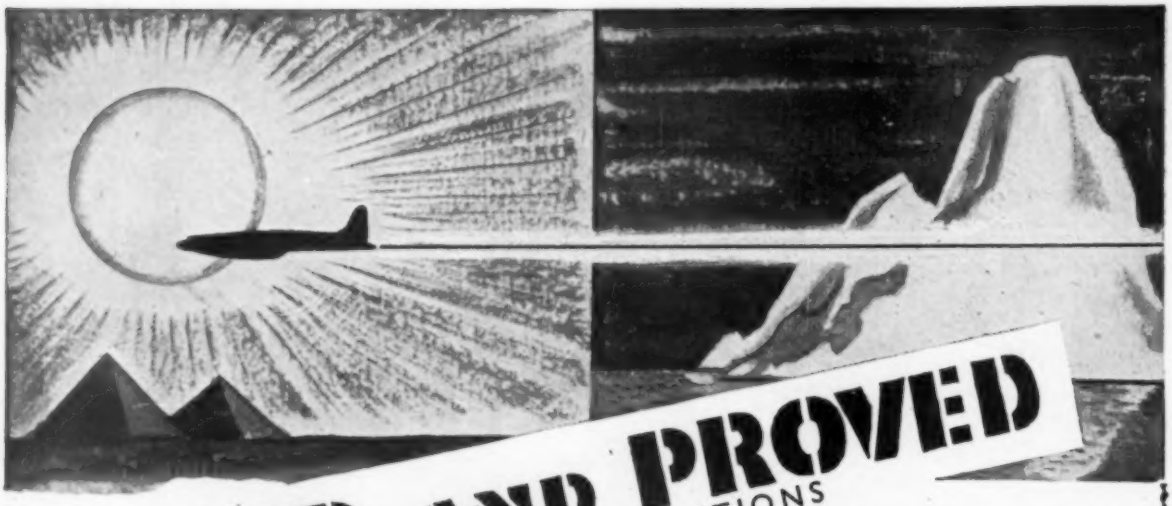

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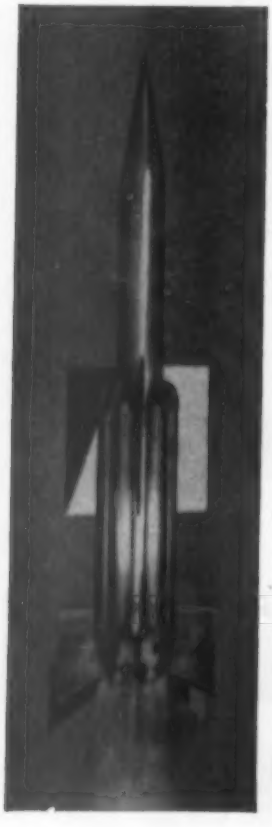

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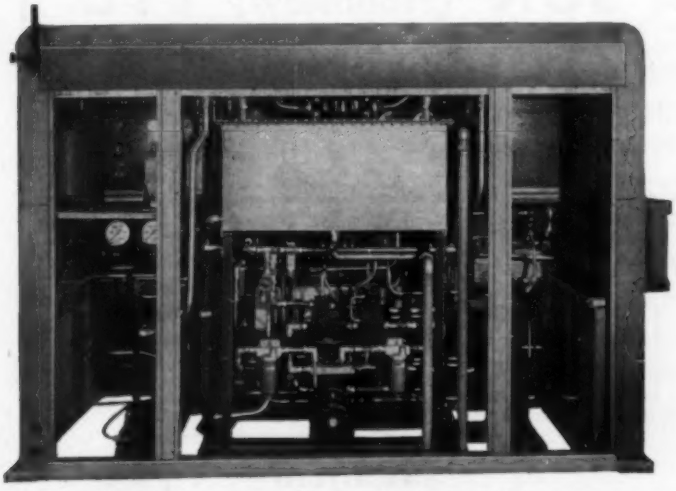

The HML Hydrostatic Test Rig rear view with shutters raised for easy access

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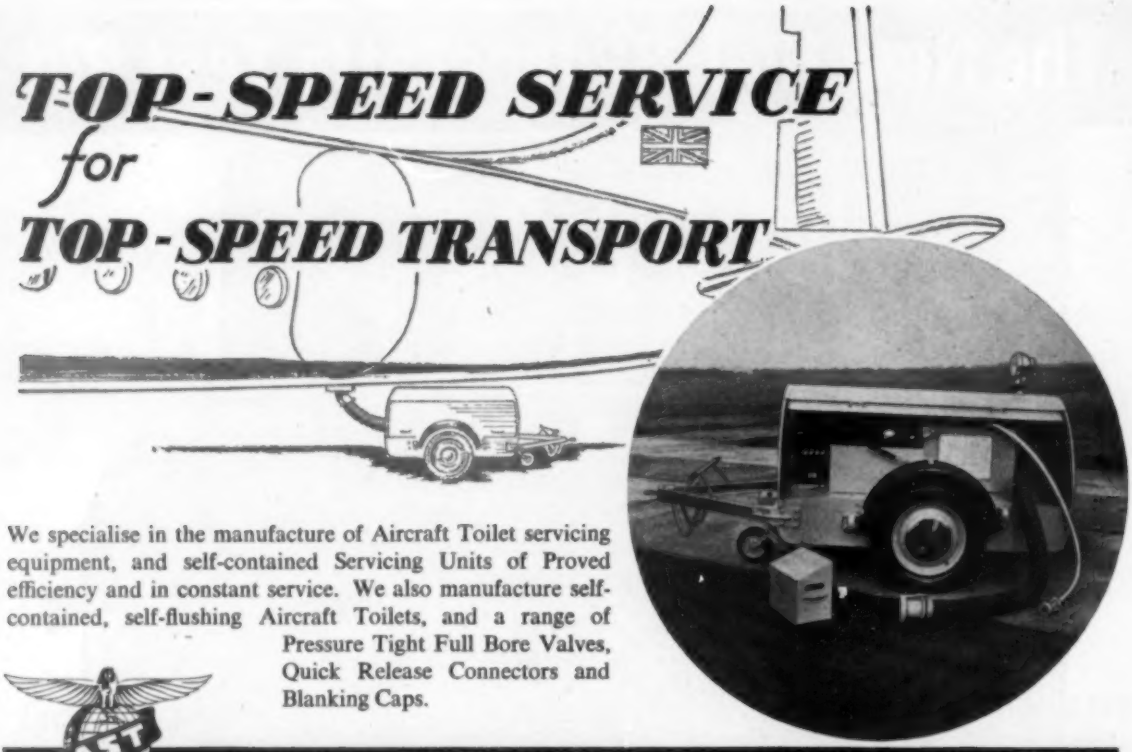

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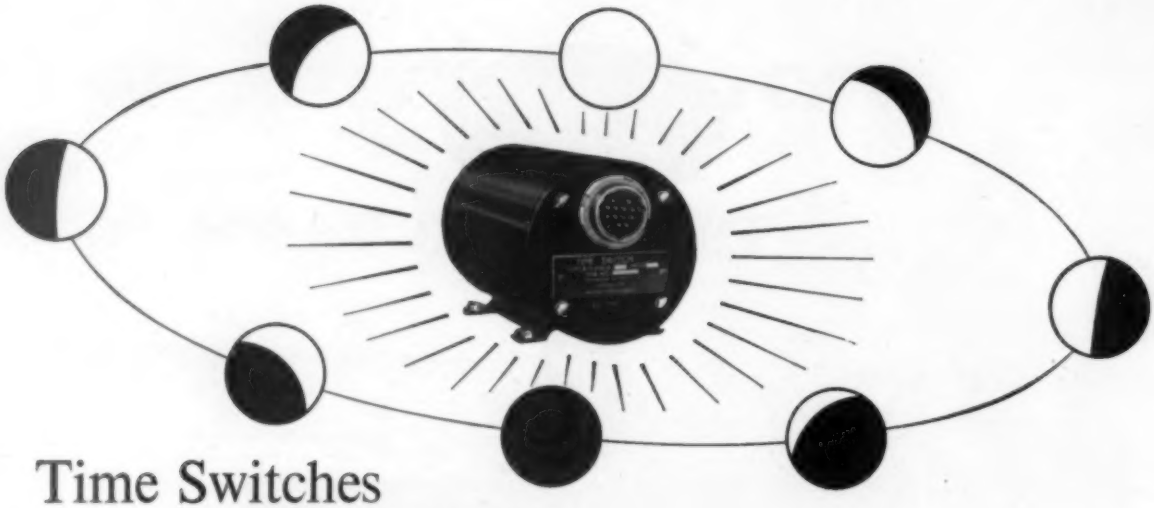

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FIRST AERONAUTICAL WEEKLY IN THE WORLD FOUNDED 1909

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. . . giving Place to New

WE present in this issue the most detailed review of the world's guided missiles yet prepared for public consumption. These devices are now usurping the functions not only of the bombing aeroplane, the fighter, and to some degree the reconnaissance aircraft, but also those of heavy and medium ordnance for use against terrestial, naval and aerial targets. Even the depth charge —seemingly one of the crudest of modern weapons—and certain of the unpretentious anti-tank devices of the infantry platoon are gradually giving way to the new, more complicated, but vastly more effective technique. That much is clear from a study of this issue.

Just as railway enthusiasts find little in electric locomotives and diesels to compare with the glamour and nostalgia of the days of steam, so most of our readers, we believe, will be a shade saddened by the gradual secession of the military aeroplane in the face of the all-conquering, laboratory-engineered, mathematically correct missile system.

But the old order is changing, and changing fast; and we shall continue to consider all types of guided weapons to be very much our business.

Clubworthiness

NOT surprisingly, there are differing points of view between those who fly and those who draft regulations concerning the ease (or otherwise) with which surplus military aircraft, sometimes ageing and usually cheap, may be converted to a useful, hardworking civil life. We refer particularly to light aircraft. Illustrative of two opposing viewpoints are the article by Elstree's chief flying instructor which appeared in our issue of November 16, and the reply from the Air Registration Board on page 870 of this issue.

The Board presents a reasoned, general account of its philosophy on the conversion question. In the case of the Chipmunk, the majority of modifications required were those which would have been incorporated had the machines remained in the Service; the purely civil alterations were few and, in several cases, minor. Yet the fact remains that the conversion in question proved a long and frustrating process and, while individual members of the A.R.B. were helpful, there was on occasion a lack of co-operation from both the Board and the manufacturers.

We of *Flight* admire the enthusiasm of the author of the original article no less than we respect the scientific integrity and sense of responsibility of the Air Registration Board. Were there no flying enthusiasts to persevere and overcome obstacles the light-aircraft movement would be in a sorry state. At the same time there is no excuse for *unnecessary* obstacles set up by the regulating authority; our best safeguard against this is the fact that, in general, the Board's decisions are based on sound technical evidence and not on any feeling of hostility towards this country's club movement.

On the contrary, the Board's record of helpful co-operation with the ultra-light aircraft movement is extremely good. The relaxation of airworthiness requirements two years ago, in conjunction with the Popular Flying Association, has resulted in a healthy growth of P.F.A. operational and constructional groups. The Board follows closely the developments of its opposite number in France, the most practical light-aircraft-minded country in Europe, and there are signs that, by joint agreement between the two countries, the scope of ultra-light air touring may well be widened.

We would suggest a similar relaxation in airworthiness requirements for *bona fide* club-operated aircraft. Normal club flying should *not* require machines licensed as "public transport aircraft." To achieve this object, club associations and organizations should cease bickering among themselves and objecting on principle to everything the A.R.B. does. A joint submission should be made to the Ministry by the club movement and the Board for such a concession. We have reason to believe that the Board itself could produce evidence to justify this step.

FROM ALL QUARTERS

Britannias for Northeast Airlines

AFTER more than the usual amount of preliminary discussion, much of it concerning purely domestic considerations, Northeast Airlines bought five Bristol Britannia 305 airliners on Monday. George E. Gardner, the airline's president, said that the initial purchase would cover five aircraft, worth over $17m, and that provision would be made for a possible future purchase.

Northeast's first three 305s are due for delivery next October, with the remaining two the following month. In service they will be used as 92-seaters on routes stretching from Montreal through New York (an under four-hour stage) to Miami (in 3 hr 15 min). High-density seating will provide for 133 passengers.

Mr. Gardner commented on the exhaustive evaluation conducted by his staff upon the Britannia and other aircraft, and said, "I am convinced we are making the wisest possible decision." He pointed out that the machine was ideal for his company's routes, would have extreme passenger appeal, would be the first 400 m.p.h. airliner in service anywhere (excluding the Comet 1 in 1952) and would set new standards for first-class travel on the American East Coast. [See photograph on page 911.]

U.S. Navy Adopts Martin-Baker Seats

IT has been announced in Washington that all U.S. Navy aircraft are to be fitted with Martin-Baker ejection seats, presumably those of the latest pattern. It is reported that existing U.S. Navy seats (which have for many years incorporated various Martin-Baker patents) do not permit safe escapes at altitudes below 300ft. The Martin-Baker Aircraft Co., Ltd., reports that a trial installation was made in a U.S. Navy fighter and that a number of seats has been ordered for this type of aircraft.

Compromise Solution

ON Monday last Mr. Charles E. Wilson, U.S. Secretary of Defense, issued a memorandum which is aimed at a joint compromise solution of inter-Service missile disputes (see p. 896).

Some points from the document are: the U.S. Army will continue to be responsible for the anti-aircraft defence of specific targets, and will thus take over the Talos (p. 901) which the Air Force wished to buy. Owing to the range of this missile, Army anti-aircraft missiles are allowed to have range up to 100 miles, instead of 50 as at present. Operation of land-based IRBMs shall be the sole responsibility of the Air Force, the Army being restricted to close-support weapons of up to 200 miles range. Army missiles shall not be fired more than 100 miles beyond "the front lines."

Meanwhile, the guided-missile cruiser *Boston* left New York last Saturday to join the U.S. 6th Fleet in the Mediterranean. There have recently been several reshuffles in American Middle-East naval strength and *Boston* should prove a most valuable addition. A new U.S. Navy missile ship is the destroyer *Gyatt*, armed with rear-mounted twin-launchers for Terrier. *Gyatt*, commissioned on Monday, is the first of a class of 16.

COMET PRODUCTION in the de Havilland factories at Hatfield, Chester and Lostock has now reached the stage where the fruits of more than a year's work on detail fabrication and tooling are becoming apparent in the shape of large and recognizable assemblies. Here Comet 4 and 4A fuselages are seen on the line at Hatfield.

GOLDEN GIFT from the Royal Aero Club to the club's president, Lord Brabazon, and Lady Brabazon on their Golden Wedding anniversary last week was a figure of Hermes. Mr. S. Kenneth Davies (centre), chairman of the club, made the presentation.

Spadeadam Missile-motor Project

IN the introduction [page 894] to the review of British guided weapons reference is made to Spadeadam Waste, Cumberland, as a site considered by the Government as "suitable for static firings of large (ICBM) motors." Last week-end, after that page had gone to press, came an announcement that the British Oxygen Co., Ltd., and George Wimpey and Co., Ltd., have formed a jointly owned subsidiary, British Oxygen Wimpey, Ltd., to construct a special rocket project there.

This follows upon the award of a large contract by the Ministry of Works and will involve the erection of buildings, plant and specialized mechanical equipment for the handling of large tonnages of liquid oxygen and nitrogen, together with ancillary accommodation for laboratories, workshops and offices.

The new company has stated that wide experience in major building contracts on the one hand, and of low temperature techniques for storing liquid gas on the other, will enable all phases of the project to be dealt with within the new organization. The chairman is Sir Godfrey W. Mitchell (chairman of Wimpey and Co.) and the managing director is Dr. L. G. Groves, of B.O.C.

The Mirage III Flies

THE Marcel Dassault Mirage III intercepter made a successful first flight at Melun-Villaroche last month in the hands of Roland Glavany. It was airborne for 40 minutes, despite indifferent weather, and reached a speed of over 460 m.p.h. The Mirage III differs from the Mirage I in having a fin and rudder of reduced proportions; a waisted fuselage conforming to area rule; a S.N.E.C.M.A. Atar 101 G turbojet giving 9,900 lb thrust and having an afterburner; and a redesigned centre-strutted, knife-edged windscreen. It is reported that interception radar is fitted, though the nose cone is still metal and carries a pressure-sensing head. Armament is to include a single missile, carried under the fuselage. The delta wing has large leading-edge flaps.

V-A. Test Pilot Appointments

TWO appointments in the test pilots' department of Vickers-Armstrongs (Aircraft), Ltd., were announced last week-end. Mr. B. G. Aston, D.F.C., becomes chief production test pilot, and Mr. D. Hayley Bell, D.F.C., joins the company as a test pilot.

During the war Mr. Aston flew 175 operational sorties in R.A.F. Ansons, Spitfires and Mosquitoes. In January 1944 his Mosquito blew up at 25,000ft over France when flash bombs exploded inside it, and he spent the remainder of the war as a prisoner. After post-war service as an airline captain he rejoined the R.A.F. in 1947 and two years later completed the E.T.P.S. course at Farnborough. In 1953, after serving as a test pilot at Boscombe Down, he left the R.A.F. to become a Vickers test pilot. Mr. Aston was awarded the Queen's Commendation for Valuable Services in the Air when, in August 1954, he safely landed the first production Valiant following loss of aileron control after a high-speed dive. Now aged 36, he has flown 4,000 hours on 127

FORTRESSES BOTH: Peeling off from a B-52 Stratofortress is a B-17 Flying Fortress of the world-renowned type first introduced 21 years ago. The B-17 weighed about 50,000 lb and was good for 300 m.p.h. The B-52 weighs over 400,000 lb and attains 650 m.p.h. plus.

types of aircraft. In his new appointment he will be in charge of production testing of Viscounts and Valiants from Weybridge, Wisley and Hurn.

Mr. Hayley Bell, aged 40, goes to Vickers from B.E.A., with whom he has served as a captain for the past ten years. During the war he flew with Coastal and Fighter Commands on Ansons, Hudsons, Havocs, Beaufighters and Mosquitoes, and was credited with five enemy aircraft destroyed. Seconded to B.O.A.C. in 1944 to fly Dakotas on the Indian and South African routes, he left the R.A.F. in 1946. He served with B.E.A. as a training captain from 1949 and in February 1953 became one of the first

Mr. B. G. Aston

Mr. D. Hayley Bell

Corporation pilots to fly Viscounts. Of his 13,000 flying hours, 3,000 have been on Viscount training and passenger flights. Since June 1955 he has been attached to Vickers to assist in Viscount delivery flights and pilot training.

Dectra Goes Ahead

DECTRA installations on both sides of the Atlantic are now rapidly taking shape. In Newfoundland the transmitter buildings are being put up and erection of the masts will be completed in January. By the end of that month both master and slave stations will be on the air with powers of 5 kW and 3 kW respectively. Concurrently the two extra slave stations necessary to establish a Decca Navigator chain in the same area will be brought into action to inaugurate the first such chain in the Western Hemisphere. In February the M.o.S. will provide a representative high-altitude, high-speed aircraft to carry out initial checks on the Dectra tracking pattern and to try the airborne crystal ranging-oscillator.

In Britain the buildings of the Dectra master station are being erected at Stirling, but the masts will not be complete until June. In the meantime the masts of the North British chain Purple slave station at the same site are to be used to transmit Dectra signals at a power of about 500 W. The British Dectra slave station will be at the North British Decca chain master station at Kidsdale.

Fairey Progress

IN his speech at the annual general meeting of the Fairey Aviation Co., Ltd., on November 29, the chairman, Mr. Roland T. Outen, referring to the F.D.2, said that with the permission of the French Government further supersonic tests had been carried out under favourable weather conditions in south-west France. He acknowledged the company's indebtedness to Avions Marcel Dassault for their valuable help.

Mr. Outen went on to say of the F.D.2:—"We have made considerable studies of possible developments of the aircraft, both for more advanced research and for military purposes, but up to the present date no orders have been given for any of this work. To us this seems strange, as we are continually hearing about such things as the shortage of technical staff and the need to make maximum use of available facilities; yet the straightforward course of building on an already well-laid foundation is not taken, in spite of the time it would save and the technical uncertainties which it would remove."

Of guided missiles, Mr. Outen said that Fireflash was now being made for use by the R.A.F. and that interest had been shown in it by several NATO countries, following a demonstration in Paris; new projects, of a long-term nature due to their complexity, were under way in the Fairey weapon division.

In the helicopter field, the Rotodyne was progressing steadily and considerable airline interest, both here and abroad, was being shown in it. Service interest, however, was not so great as the company would like, though they felt that the ability to transport five-ton loads 400 or 500 miles, without the need for runways, made the Rotodyne a vehicle of great potential use for military purposes.

Mr. Outen went on to speak of the Gannet, which, he said, was giving "excellent service" in the Royal Navy and was highly spoken of by the Royal Australian Navy. "You may feel disposed to ask why the Gannet receives less publicity than some other types of aircraft," he continued. "The answer, odd as it may seem, is that the very success of the Gannet keeps it out of the news." Nevertheless, the Gannet's performance had not escaped the notice of other Governments; and negotiations for a contract with West Germany, to a value of approximately £2,500,000, had reached an advanced stage. Design work was now proceeding on a new version of the Gannet, intended to take over the search duties at present performed by the Douglas AD-3W Skyraider.

In a reference to hydraulic controls, Mr. Outen said that those made by Faireys continued to be used in several British aircraft and that the latest to fly with them were the Vickers-Supermarine N.113 and the Canberra P.R.9.

In his statement on the company's financial position, Mr. Outen said that the consolidated group trading profit for the year, before providing for taxation, amounted to £2,065,097, compared with

FINDER AND FIXER: Among Fleet Air Arm units engaged in the recent action in the Eastern Mediterranean was No. 809 Sqn. which flew from H.M.S. "Albion." The C.O., Lt-Cdr. R. A. Shilcock, and Senior Observer, Lt. J. W. Hackett, here stand by one of the squadron's Sea Venoms. It has the bulged canopy and Martin-Baker Mk 4 lightweight ejection seats which distinguish the latest version.

FROM ALL QUARTERS . . .

a figure of £2,159,568 in the preceding year. There had been some reduction in the profits of the parent company, but this was largely offset by increased profits from the overseas subsidiaries.

After adjusting for profits relating to the interest of minority shareholders in subsidiary companies, the group's net profit amounted to £898,322, an increase of some £96,000 over 1955. With profits retained by subsidiary companies deducted, a balance of £671,895 was left in the parent company's accounts. To this was added the balance of profits brought forward from 1955, giving £809,418 as the final amount available, compared with £714,810 last year.

Finally, Mr. Outen reviewed the work of the subsidiary companies. He welcomed three directors of the Fairey Aviation Co. of Canada, Ltd., Mr. Shirley Dixon, Q.C., Senator Charles Hawkins and Mr. C. E. Hibbert, who had recently come over for consultation with the parent Board and were attending the meeting. He went on to say that the company's works at Halifax, Nova Scotia, had been engaged mainly on the repair and modification of Avengers and Lancasters for the R.C.N. and R.C.A.F., and the manufacture of Fairey Hydro-booster units for Avro Aircraft, Ltd., Canada. Banshees and Neptunes were now being sent to the company for overhaul.

Referring to the Fairey Aviation Co. of Australasia, Mr. Outen said that Fireflies in the Royal Australian Navy were now being replaced by Gannets; and that at Salisbury, South Australia, the company's special projects division had been occupied with a number of projects (some of them secret) and had in addition backed up the large contingent of technicians from the Fairey weapon division there who continued the advance trials of Fireflash at Woomera.

The Belgian subsidiary, Avions Fairey, had made good progress in fulfilling the Hunter programme on which it is collaborating with SABCA; and during the year under review Fairey Air Surveys, Ltd., had been engaged in extensive operations in many parts of the world, probably the most important being the survey of the Zambesi Basin for the vast Kariba Gorge hydro-electric scheme.

Royal Aero Club Occasion

EIGHT representatives of varied branches of aviation were honoured at a Royal Aero Club house dinner on Tuesday, November 27. They comprised world champions in the spheres of gliding and model flying, and recipients of Paul Tissandier diplomas of the F.A.I. for 1955. In the absence of the R.Ae.C. president, Lord Brabazon, who was celebrating his 50th wedding anniversary, the chairman of the dinner was Mr. S. Kenneth Davies, chairman of the club. The guests of honour were:—

Cdr. H. C. N. Goodhart, R.N. (absent through illness) and Capt. Frank Foster of B.E.A., two-seater class champions in the 1956 World Gliding Championships.

Mr. R. L. Draper and Mr. Raymond Gibbs, respectively individual world power model champion and holder of the world model speed record (131 m.p.h.).

The following recipients of the 1955 Paul Tissandier diplomas of the Federation Aeronautique Internationale: Mr. E. C. Bowyer, C.B.E., who was awarded the diploma for his work as director of the S.B.A.C.; Mr. L. L. Bridgeman, for his work as compiler and editor of *Jane's All the World's Aircraft*; Mr. P. B. Mayne, for his work as Royal Aero Club timekeeper and starter; and W/C. W. R. Parkhouse, M.B.E., for his pioneering work in connection with civil aviation in the West Country.

Also present at the dinner were Mr. C. F. Uwins, president of the S.B.A.C., and Capt. K. Bartlett, former president of the F.A.I. Photographs appear on page 872.

CIVIL CONVERSIONS: THE A.R.B. VIEW

Philosophy of Airworthiness Certification for Surplus Military Aircraft

FOLLOWING the article "Chipmunk Conversion" by David F. Ogilvy in our issue of November 16, we received a letter from the secretary of the Air Registration Board pointing out that there was another "and by no means unreasonable" side to the story. At our invitation, a fuller statement of the Board's philosophy concerning the civil certification of surplus ex-military aircraft was prepared; it is given in full below.

RECENT articles in the aviation Press have focussed attention on the difficulties of securing a Certificate of Airworthiness for ex-military surplus aircraft. The articles referred particularly to the smaller aeroplanes, and the implication was that the Board acted in a generally officious and obstructive way.

There are, of course, a variety of points of view as to the attitude which should be taken towards the "civilizing" of ex-military aircraft. The owner, initially delighted by the acquisition of an aeroplane for a fraction of its cost when new, is dismayed to find that certification is more than a formality. The constructor attempting to find a market for new aeroplanes is critical unless the acceptance conditions for the ex-military aeroplanes are comparable to those applied to his own product. Should an ex-military aeroplane subsequently suffer an accident in any way attributable to failure to apply normal civil standards, the persons involved, or their relatives, have grounds for serious complaint. Finally, any suggestion that civil standards are superior to military ones can be construed to mean that the R.A.F. pilots have been exposed to unnecessary risk.

It is evident that, with all these potential sources of pressure, no action by the Air Registration Board is likely to be unanimously popular. Fortunately one usually finds that the more impassioned cries of outrage are the ones of least substance. The Board must attempt, to the best of its ability, to find a course which, whilst ensuring safety, is as fair as possible to all parties.

One of the most important considerations is the physical condition of the aircraft and its equipment. It is not always possible to trace the history of the aeroplane (or its engines or equipment) with any precision. Sometimes the storage conditions, in the interim period between ceasing to be used by the R.A.F. and purchase by a civil user, give rise to doubts about the risk of corrosion. Superficial inspection provides little guide as to the real condition, and one is often forced to complete dismantling and overhaul as the only safe way of checking.

An allied matter is the modification standard. Service experience has indicated that certain (and often very numerous) modifications are necessary. But if the particular aircraft has been at a disposal depot for some time, its modification standard is not always up to date. Again, work is necessary to rectify these matters.

In the case of aeroplanes built during the war, concessions in materials and protective treatments were not infrequently granted. These were reasonable, in the circumstances prevailing at that time, when aircraft were destined for a short military life. However, records of details of such concessions are no longer available, so again doubts are raised as to the extent to which the aeroplane may be sub-standard. The impossibility of determining the actual airworthiness standard of some of the older ex-military aeroplanes has led the Board to refuse to consider them for certification.

It is, of course, true that in the immediate post-war period ex-military aircraft entered civil service with a bare minimum of investigation and reconditioning. This was consistent with the desperate need of the country to re-build its civil operations. Moreover, it was visualized that these aeroplanes would be fairly rapidly replaced by more suitable aircraft.

A point which is often criticized is the fact that the Board, having certificated aeroplanes of certain types in the immediate post-war days, may no longer be willing to do so if further aeroplanes of the same types become available. This is a particular example of a general problem faced by all airworthiness authorities; namely, when a higher standard of airworthiness is introduced, should it apply retrospectively? The Board usually follows an arbitrary procedure of allowing already certificated aeroplanes to proceed to the end of their useful life, but to require the higher standard in respect of newly introduced aeroplanes. This sometimes leads to anomalies, but it seems preferable to a policy of never seeking to raise the standard, or to one of putting existing fleets out of business on each occasion that the standards are raised to a new level.

Application of civil design standards to ex-military aeroplanes raises another difficult issue. There are good reasons why the standard for civil and military aeroplanes should not artificially be forced into precisely the same mould. The military pilot and crew usually—if not always—wear parachutes, while it is rare for civil pilots and passengers to do so. In order to obtain an efficient military aircraft it may be necessary to reduce certain pure airworthiness standards. The overall safety of the pilot of the military aircraft may well be raised thereby, particularly in combat conditions. But the same consideration would not apply to the civil case. In other ways, such as utilization of aircraft and the minimum physical standard of the pilots, the military and civil backgrounds differ. Generally, however, it is found that the basic design of the military aircraft is reasonably in compliance with civil standards, and it is in detailed matters that modification is required.

It could be—and often is—argued that such detailed points do not materially influence the level of airworthiness. However, in the field of airworthiness one is rarely dealing with a simple

matter of absolute safety or absolute danger. Rather it is a question of the difference between two degrees of safety. Thus, where a civil requirement has been developed over the years, and is accepted by the industry and operators as a necessary standard, it is difficult to justify ignoring it where an ex-military aircraft is concerned.

A point which is not always appreciated is the extent to which the Board has to defend the United Kingdom Certificate of Airworthiness against criticism from foreign airworthiness authorities. Defects, accidents or incidents to British aircraft which have been sold abroad not unnaturally lead to doubts being cast on the level of airworthiness offered by the British aeroplane. Some criticism is justified; other criticism is not. It is, however, very important that the Board should not expose this country to justifiable criticism by ignoring the safety standards which have generally been accepted as necessary.

Recent articles have quoted the Chipmunk as a particular example of the treatment meted out to the ex-military aircraft. A point-by-point answer seems barely justified, but it is of interest to note that, of the modifications listed by the Board as necessary to achieve a civil certificate, 22 had previously been embodied by the constructor and 34 were listed by the R.A.F. for embodiment (had the aircraft remained in the R.A.F.). The remaining 11 modifications were the purely civil extras. In spite of the alleged difficulties, one club has now obtained Certificates of Airworthiness for 14 Chipmunks.

The suggestions contained in previous articles that the Board's decisions are bureaucratic cannot be accepted. It may be that in reaching particular *ad hoc* decisions the Board is not infallible. Sufficient has been said to show that the question of acceptance standards is by no means an easy one. Articles which present one side only of the picture, and whose aim is to discredit the Board's efforts, do little more than add to the grey hairs (or remove the few remaining ones) of a group of persons which is always prepared to consider constructive proposals for changes of outlook or of method.

SIR THOMAS SOPWITH REMEMBERS

FOR their first reunion dinner, held early this year, the Sopwith Apprentices Association chose the London Airport restaurant. For the second, which took place last week, they selected the exclusive and sybaritic surroundings of the United Service Club in Pall Mall. It was appropriate that the occasion should thus be made a rather special one, for the guest of honour was Sir Thomas Sopwith, the great aviation pioneer who founded the original Kingston-on-Thames business out of which was to grow the bigger Hawker Company, and, ultimately, the vast Hawker Siddeley Group. The managing director of that organization was another of the distinguished guests.

Speeches were, of course, mainly reminiscent, and through nearly all of them ran a note of affection for Mr. Fred Sigrist, initially chief engineer of the Sopwith company and later one of the founders of the Hawker business; today, illness compels him to live in the Bahamas.

Taking as his text a telegram from Mr. Sigrist—"PITY WE ARE NOT 40 YEARS YOUNGER WOULD THEN KNOW BETTER THAN TO MESS AROUND WITH AEROPLANES"—Sir Thomas wondered whether Fred hadn't got his tongue in his cheek. Were they quite so crazy in those days? "Flying was fun then—we built and flew aircraft simply for the thrill of it."

From here Sir Thomas went on to reminiscences which clearly delighted his audience. He recalled personalities; he remembered aeroplanes and what happened to them. There was the time when the Sopwith Baby seaplane, prepared at Kingston (with one of the first 100 h.p. Mono Gnômes) for the 1914 Schneider Race, was taken down to Hamble for testing by Howard Pixton; there was engine trouble, a drifting and towing episode, and eventually a nose-over which, when the tide ebbed, left the aircraft standing vertically in the mud on its propeller hub and single central float.

"We threw the wings away," said Sir Thomas, "sawed up the float, and rebuilt the airframe—*in three days*. Then we took the Baby to Monte Carlo and won the race." [The single float, we believe, was sawn in half and rebuilt to make a pair.]

And there was the American competition in which the aeronauts had to cross to their aeroplanes, get in, taxi out and take off, the whole process being stop-watched to the moment of unsticking. "We won in nine seconds," said Sir Thomas, adding, "Today you can't *get into* an aircraft in nine seconds!"

Arriving back from a visit to Armstrong Whitworths just too late to figure in the accompanying photographs was Sir Frank Spriggs, who maintained that, whether those early days were crazy or not, he had "just come from Coventry, where I've seen something —— crazy."

Less enigmatically, he went on to recall some Hawker highspots —highest of all, in his opinion, being "the day they authorized Hurricane production without an order."

Half-a-dozen other hosts and guests, in their turns, contributed to the fund of recollection. Mr. J. H. Williams recalled the "Sigrist Bus," prototype of the 1½-Strutter, and how trouble with its c.g. was cured by (a) tying lead to the tailskid and (b) putting erection-shop foreman "Big Charlie" (a sparring-partner of Hackenschmidt the wrestler) in the front seat, "with the back end of the crankshaft touching his tummy." S/L. Joe Taylor (guest from the 504 Club) recalled being detailed, in 1916, to spend some days in an empty hangar, until at last there arrived a 1½-Strutter, signifying the birth of "A" Flight, 70 Sqn.

A.V-M. L. T. Pankhurst (erstwhile Sopwith apprentice) recalled the various Kingston-built types he had flown—Snipe, Fury, Osprey, Hurricane—as being what he liked to call "pilot's aircraft." Mr. R. W. Sutton (the evening's chairman) looked back to days when the Sopwith D.O. staff climbed to the roof to watch Harry Hawker fly Schneider seaplanes off the Thames at Kingston, only to find themselves "driven back to our drawing-board by a clout on the backside with a tee-square from Fred Sigrist."

Altogether a good reunion; a little clannish, perhaps—which is just what a good reunion should be.

At the reunion: (Left) Sir Thomas Sopwith and Mr. R. W. Sutton. (Below, left to right) Mr. Neville Spriggs and Mr. J. D. Stranks; Mr. V. W. Derrington (secretary of the Association) and Mr. L. A. Pollard; Capt. Duncan Davis, Mr. J. H. Williams and Mr. S. C. Goodenough. "Flight" photographs

HERE AND THERE

TILTING WINDMILLS: The latest Transcendental convertiplane ("Convertibility" below).

Independent Merger?

BY the time these words appear it is likely that the British Aviation Services group (parent company of Silver City, Britavia, Air Kruise, Manx and Aquila) will have completed negotiations for the purchase of the Lancashire Aircraft Corporation. L.A.C. operate scheduled domestic services from Blackpool with DC-3s and Rapides.

German Air Attaché

THE new air attaché at the Germany Embassy in London is Colonel Hans von Ploetz. A former Luftwaffe officer, he was imprisoned in 1944 as one of the instigators of the plot on Hitler's life, but later released.

Septuagenarians

TWO pilots who are probably the oldest in the world to hold current flying licences, Mr. J. R. Franklin (who is 73) and Mr. E. V. West (72), gave a five-minute display at Milson Airport, Palmerston North, New Zealand, during the recent agricultural aviation show there. Mr. West did not learn to fly till he was 58.

R.Ae.C. Helps Hungarians

WHEN Royal Aero Club members volunteered to fly Hungarian refugees to this country in their own aircraft, a generous private gift was made towards the cost of fuel that would have been used had the airlift taken place. Now the R.Ae.C., at the suggestion of the donor, has given from it £150 to each of the three organizations associated with the airlift plans: the International Help for Children, the Save the Children Fund, and the British Red Cross Hungarian Relief Fund.

Convertibility

ILLUSTRATED above is the Transcendental Aircraft Corporation's latest tilting-rotor convertiplane prototype, designated Model 2. The first machine suffered ground resonance and was destroyed in 1950. A further machine, the 1-G, was built for ground testing, then modified for flight under U.S.A.F. contract. During 1954 and 1955 it made more than 100 flights and achieved 90 per cent conversion (about 70 deg forward rotor tilt), before failure of the friction lock on the collective-pitch lever caused a forced landing in the River Delaware. The Model 2 has more power and greater wing-area and should make its first flight early next year. It is powered by a Lycoming O-435-23 of 250 h.p. and weighs 2,249 lb. Useful load is 670 lb.

R.Ae.S. Film Show

A FILM on the Comet accident investigation will be among four due to be shown at the Royal Aeronautical Society Graduates and Students Section meeting at 4 Hamilton Place, London, W.1, on December 7. Other titles include *Rig 20* (the story of an oil fire) and *Mille Miglia 1953*.

D. H. (A.) Chief Pilot Resigns

IT is announced that G/C. Brian R. Walker, who has been chief test pilot of the de Havilland Australian company since 1946 and was responsible for the flight development of the Drover, has resigned to join Gibbes Sepik Airways, Ltd., of New Guinea. G/C. Walker is at present in Sweden collecting two Ju 52s, newly powered with P. and W. Wasps (see *Flight*, September 7) for operation in New Guinea.

Changing the Emphasis

WELL known as an air correspondent—in recent years for the London *Evening News*—Mr. Cyril Birks is giving up that particular post in order to devote more time to the publicity and public relations work of Birks-Thorne, Ltd., of which company he is a director. He will not, however, forsake aviation journalism entirely. The other half of the partnership is Mr. Alex Thorne, D.S.O., D.F.C., who until last June was secretary-general of the Pathfinder Club, and who continues as a council member and editor of *The Marker*.

Pilots' Panel

SEVERAL chief test pilots will answer members' questions at the next meeting of the London Society of Air-Britain (Caxton Hall, Westminster, Wednesday, December 12, at 7 p.m.; test pilots, 8.30 p.m.).

Power on the Farm

COVERING the whole field of mechanization in British agriculture, the first monthly issue of *Practical Power Farming* is now on sale. Consisting of 68 newspaper-style pages, and priced at 1s, it is the 2s 6d monthly journal *Power Farmer* in new form.

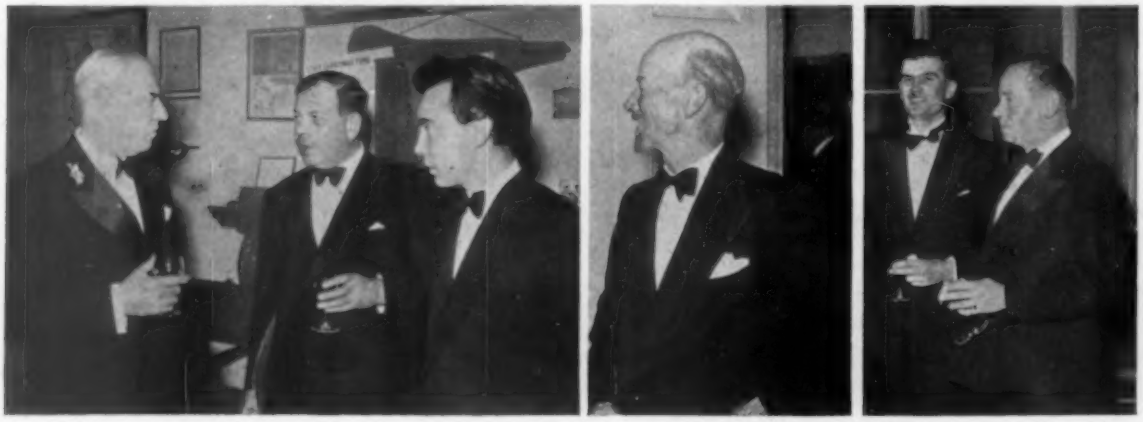
R.Ae.S. Presidential Address

THE president of the Royal Aeronautical Society, Mr. E. T. Jones, is to deliver his presidential address to members on January 10, with Lord Brabazon in the chair. The address (6.30 p.m.) will be followed by a reception (7.30 p.m.), with buffet supper and film show. Venue and times have been changed from those originally announced.

For Bismarck Read Arminius

THE helmeted head behind the Swift F.R.5 in *Flight* last week was not, we discover, that of Bismarck—as stated by the Air Ministry—but of Herman (Arminius), the German national hero who, by destroying three legions in A.D. 9, forced the Romans to withdraw their frontier from the Elbe to the Rhine. His monument, on the Grotenburg mountain at Detmold, was completed in 1875.

VARIED ACHIEVEMENTS in aviation were honoured recently at the Royal Aero Club (see page 870). From the left are Capt. K. J. G. Bartlett, Col. R. L. Preston, Mr. Raymond Gibbs, W/C. W. R. Parkhouse, Capt. Frank Foster and Mr. P. B. Mayne.



Prediction or production

We do not presume to probe
or predict the aeronautical future.
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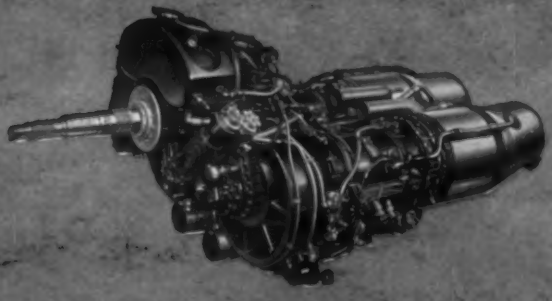
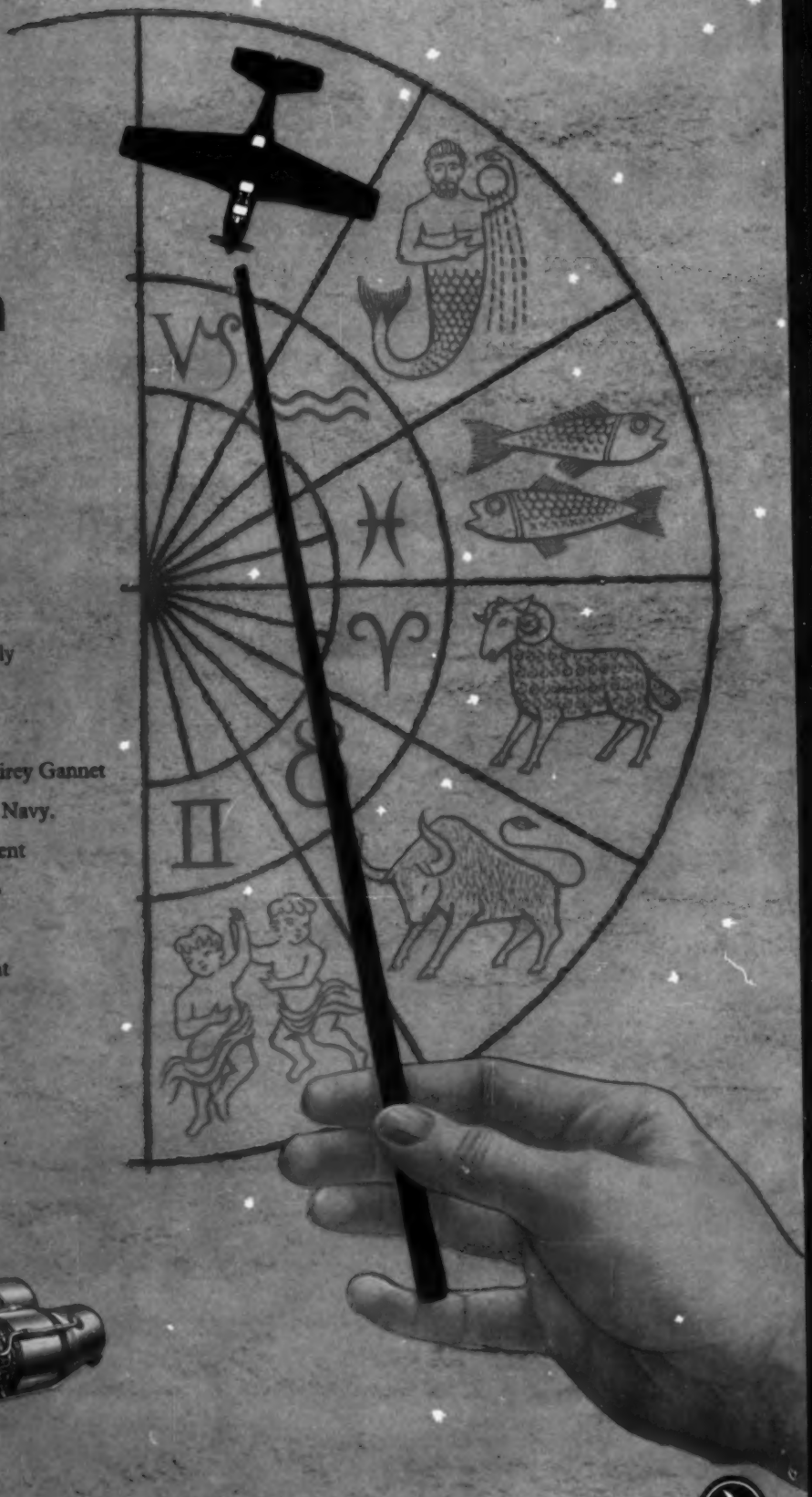
doing, and doing very thoroughly,
the things that must be done *now*—
in further developing, under ruthlessly
realistic research and test
conditions, such engines as the
Double Mamba, designed for the Fairey Gannet
anti-submarine aircraft of the Royal Navy.
For we believe that future achievement
is secured by present perseverance—
that by concentrating all our
effort on the continuous development
of proven types like these,
we are making a truly practical
contribution to this
country's command of air and sea.





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When it comes to cigarettes, one name immediately comes to mind as standing for the best—STATE EXPRESS. For well over half a century, in every part of the world, State Express 555 have been recognised for finest quality and it has become a tradition that State Express 555 and Christmas go together.

The complete range of State Express cigarettes available for Christmas Gifts is an impressive one and the prices are not high. Imagine the delight when parcels are opened on Christmas morning to reveal a handsome pack of 555! Undoubtedly, Christmas is the time for 'everything of the best' and nothing fits the occasion better than State Express.

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You can see these wonderful value tankards in all the good tobacconists' windows now. They are made in Sheffield in the traditional hammered finish with a glass base, and each contains a round airtight tin of 50 State Express 555. An excellent gift for any male and highly appropriate to the festive season! The 1-pint size costs 39/6, and the ½-pint tankard 30/-.

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In beautifully ornamented pottery, with characters from Dickens modelled in relief. Colourful and decorative and containing an airtight tin of 50 State Express 555 cigarettes—29/6.

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The airstrip at McMurdo Sound, advanced base for Operation Deep Freeze.

ANTARCTICA

—and Aviation: its Growing Civil and Military Potentialities

By FRANK ILLINGWORTH

THESE next few months will see more aircraft in the Far South than at any time in polar history. By the end of next month no fewer than eleven nations are likely to have constructed airstrips there. Some of these sites may, perhaps, become of predominantly military significance; others will certainly be developed into staging-points on new trans-Antarctic air services between Australia and South America, South Africa and South America. In fact, the extension of aviation to and across the Far North is now about to be repeated in the Far South, in both military and civil fields.

The Soviet Union and the United States lead in the military sphere. The U.S.S.R., for example, is now believed to maintain in the Antarctic aircraft with the range to reach Australia's major cities and return to base; and the U.S.A. is gaining valuable experience from its "Deep Freeze" force of aircraft in the Far South, which includes Globemasters and Skymasters operating from bases at the South Pole and at strategical points on the coast of the Antarctic Continent.

As for South Polar developments in civil aviation, several countries have formed concrete plans for Great Circle routes across what is popularly called "the bottom of the world." It was rumoured in Oslo recently that Scandinavian Airlines were to inaugurate, during the coming Antarctic summer, proving flights from Copenhagen to Melbourne *via* the South Polar regions, though this was subsequently denied. From Canada and France come firm announcements on this theme. Mr. Grant McConachie, president of Canadian Pacific Air Lines, has announced officially that C.P.A. has extended its Europe-Canada - South America services to Buenos Aires with a view to a new service to Australia *via* Antarctica. This means a new Great Circle route between South and North Polar regions.

As for France, the French Department for Overseas Territories has constructed, in the Kerguelen Islands, two 6,000-yard airstrips. The Kerguelens—a rugged, volcanic archipelago—lie on the edge of the Southern Ocean. The French settlement there includes a building with a comfortable lounge-bar and living quarters; workshops and meteorological station; and a farm producing beef, mutton, pork, reindeer meat, chickens, ducks and greenhouse-raised vegetables. Equally interesting is the fact that the Kerguelens lie roughly mid-way between Australia and South Africa; and if the present routes between (say) Cape Town and Sydney are somewhat roundabout the direct route between Cape Town and Sydney is only 6,470 miles, with one stop—at French Farm, Kerguelen.

That Britain was alert to the potential value of Antarctica was illustrated when, during a depressing period of the last war, she

The crew of the U.S. Navy R4D which made the first landing at the South Pole, five weeks ago. (Right) Preparing one of the large pallets on which heavy gear—including tractors—is now being air-dropped at the South Pole.

Mountains 15,000ft high, photographed from a Deep Freeze aircraft flying between McMurdo Sound and the South Pole; Sir Edmund Hillary will have to sledge through country of this kind for his link-up with Dr. Fuchs' expedition next year. (Right) Rear-Admiral G. J. Dufek, in command of the Deep Freeze operation under Admiral Richard E. Byrd.

ANTARCTICA . . .

despatched an expedition to an island off frozen, ice-capped Graham Land—the riven peninsular that sweeps away from the Antarctic Continent towards Cape Horn (and today lies on the "direct" Australia-South America air route). That was in 1943. Subsequently survey flights of Graham Land were made with an Auster based on a second outpost in Graham Land, that at Marguerite Bay. And now, of course, part of the Falkland Islands Dependencies (which embrace Graham Land and its flanking ice-capped archipelagos) are being mapped from the air, and the Commonwealth Trans-Antarctic Expedition is on its way south to make the first overland crossing of the Antarctic Continent *via* the South Pole, with air support (Beaver, Otter and Auster).

British trans-Greenland exploration laid the foundation for Europe-Canada air services *via* the North Pole. No less will the Commonwealth Trans-Antarctic Expedition, under the leadership of Sir Edmund Hillary and Dr. Vivian Fuchs, with their supporting route-finding aircraft, help towards founding new trans-*south*-polar air routes.

North Polar air schedules were founded on three necessities: (1) aircraft with the range and reliability to span unexplored and uninhabited arctic wildernesses, (2) staging points in Iceland, Greenland and Alaska and (3) network of meteorological stations. Similar fundamentals are necessary to trans-Antarctic air routes; and, here again, Britain has done much towards their realization—more, in fact, than any country other than the United States.

British Antarctic territories—the so-called Falkland Islands Dependencies—are well situated as staging-points. Since 1943 the United Kingdom has built up there a veritable network of permanent meteorological stations, which this last year have been extended to the ice cliffs of the Weddell Sea and in the coming year will be extended into the unknown interior of the White Continent itself.

No less are the Australian and New Zealand Antarctic territories of great potential value to aviation; and, of course, these two Dominions have done much to lay official claim to them. New Zealand is to establish bases on McMurdo Sound, on the opposite side of Antarctica from the Weddell Sea, as part of the Commonwealth effort to cross the White Continent *via* the South Pole; she has also a met. station on Campbell Island, between New Zealand and the southern ice fields, while Australia has established four met. and scientific stations in the Far South, one of them on the ice cap. South Africa, too, is in the Antarctic picture, with meteorologists on three islands on the edge of the Southern Ocean.

Other countries contributing to the growing chain of South polar met. stations are the Soviet Union (3), U.S.A. (7), France (3), Norway (1), Japan (1), Argentine (8) and Chile (3). Altogether, there are nearly 50 stations.

In addition automatic recording/transmitting apparatus is to be established on the 10,000ft-high ice cap. Equipment now being

The two aircraft of the British expedition to the Antarctic, an Otter and an Auster, on the deck of the expedition's ship Magga Dan, which recently sailed from London.

Soviet Russia has been making a number of Antarctic reconnaissances, and it is believed that Mi-14 helicopters (above) have been used; Il-12s (right) have also taken part.

taken south by Commonwealth expeditions includes the Grasshopper, which, dropped from the air, raises itself on six legs, opens itself, records meteorological data and transmits coded results at 17 groups a minute. The whaling fleets are another source of meteorological information, at least during the Antarctic summer.

So the foundation of a South Polar met. network has been laid, and radar equipment, too, is now being ferried south. Aircraft with the range to span Antarctica are available. And the third necessity to trans-Antarctic civil aviation—staging points? These, too, will soon be available; some, indeed, are already in being used by aircraft—for instance, the U.S. base on the Ross Sea ice and at the South Pole (both founded under Operation Deep Freeze).

Russian explorers at the new Soviet research base in the Australian Antarctic Territories (the Russians are there with Australian permission) have laid out an airstrip and installations adequate for four-engined aircraft. Probably, of course, we shall be told little about Soviet aviation in the Far South. The United States, however, has published its plans. It has announced that one of its aircraft, of undisclosed type, has made a double crossing of Antarctica, operating from the Ross Sea base; and it has published the overall plans of Deep Freeze. With the arrival of the Antarctic summer last October, Globemasters, Skymasters and other aircraft returned to the airfield built on the ice of the Ross Sea during the previous year and an airstrip and settlement has now been established at the South Pole itself, by parachute and airlift.

The scale of the American venture can be seen in the 50 flights Globemasters alone are to make across the South Pole this present Antarctic summer and the million gallons of fuel that the operation will consume. In addition there will be U.S. bases on Vahsel Bay (Weddell Sea), at Little America (Kainan Bay) on the Beardmore Glacier, on the ice cap at approximately Lat. 80 deg S Long. 120 deg W, and on the Knox Coast in the Australian Antarctic Territories.

The Antarctic Continent embraces an area the size of Britain, Europe, the Mediterranean Basin and the fringe of North Africa as far as Suez. Almost entirely covered with ice, much of it thousands of feet thick, subject to intense cold (100 deg and more of frost) and fantastically strong winds, it is flanked by seas that are frozen for the greater part of the year and during the "open" season covered with pack-ice studded with bergs. Nevertheless, Antarctica is of growing importance, and its importance will increase as atomic energy, automation and aviation develop.

Undoubtedly one reason for present activity in the Antarctic is its increasing strategical value. In any major war the Suez Canal may well be closed to Commonwealth and United States shipping. The political situation in the countries flanking the Panama Canal is not always stable. Were the use of the latter, or both, canals to be denied, shipping between the Atlantic and Pacific would have to use the old round-the-Horn route. The Graham Land Peninsular, which, of course, forms part of Britain's Falkland Islands Dependencies, points towards Cape Horn like a crooked finger. Graham Land and its flanking archipelagos could, in an emergency, provide sites for air bases. Royal Marines from H.M.S. *Protector* made experimental landings on these frozen coasts this time last year, using a helicopter. *Protector* is now south again, and further landings will be made this month and next.

Meanwhile, facilities at the British airstrip on Deception Island, 700 miles from Cape Horn have been improved; and when one considers the speed with which the United States constructed the great airbase at Thule, in extreme north-west Greenland, it should not be beyond U.S.-U.K. "know how" to construct a major base in Graham Land or on one of its outriding archipelagos. Such a base could have a considerable bearing on the security of the round-the-Horn sea lane; and, of course, it could be supplemented in summer by seaplane and flying-boat bases and by gravel airstrips for summer and winter use, and in winter by airstrips laid on the ice.

That warships can operate among the southern "pack" is proved by the annual round which a major unit of the Argentine Navy makes in British South Polar waters, by H.M.S. *Protector* and other R.N. ships, and, of course, by the massive armed icebreakers of the U.S. Navy. It is doubtful whether aircraft carriers could operate in Antarctic waters. However, with a base on the Falkland Islands, and others in the Falkland Islands Antarctic Dependencies, British sea and air power could go at least a long way to controlling round-the-Horn sea traffic. And, of course, it must not be forgotten that the United States is to build an important base in this same territory, one that can receive aircraft from New Zealand *via* the U.S. Ross Sea Deep Freeze base in two "hops."

One of these crossings is from New Zealand to Antarctica, a flight which has already been accomplished at least three-score times; and the other is the width of the Antarctic Continent from the Deep Freeze base to that to be built by the United States on the Weddell Sea's ice cliffs.

It is hardly surprising that a British Commonwealth Air Force Committee should have been sitting, in Wellington, to discuss possible aviation developments in the Far South!

Speaking in Canberra recently, Mr. Richard Casey, Australia's Minister for External Affairs, emphasized the strategic importance of Antarctica to Australia. Sir Douglas Mawson, veteran Australian explorer after whom the Dominion's main base on the Antarctic Continent is named, has said it was "disturbing" from a defence point of view to see so many countries setting up scientific bases in the Antarctic, under the overall plan for the International Geophysical Year. He put forward the view that Australia could be bombed from these bases and that the Dominion should herself build a base in Antarctica, by airlift from Hobart, Tasmania. He also said that it would be interesting to see if the countries that established themselves in Antarctica during the International Geophysical Year would withdraw from it when "the Year" ended.

C-130 ARCTIC TRIALS

THE first Lockheed C-130 Hercules to undergo Arctic trials was due to leave for Eeilson A.F.B., Alaska, early this month. It has been specially equipped by the U.S.A.F. Wright Air Development Command at Wright-Patterson A.F.B., Dayton, Ohio, and is expected to remain in the Arctic for one or two months. First deliveries of C-130s to the U.S.A.F. were mentioned in *Flight* for November 30.

SCIENTIFIC RESEARCH GUIDE

A USEFUL quick-reference guide to scientific research at present being carried out at British universities and university colleges has been issued by the Department of Scientific and Industrial Research, with the agreement of the Agricultural Research Council and the Medical Research Council. Material for the publication, *Scientific Research in British Universities, 1955-56* (H.M.S.O., 21s; or by post, 21s 7d), has been collected by the British Council from the heads of university departments.

As in previous issues, entries are arranged in alphabetical order of universities and university colleges; names of those permanent members of the staff actively engaged in supervising research are listed, and against each name is a broad description of the work.

MISSILES THAT THINK

AN INTRODUCTION TO GUIDED WEAPONS

By the Technical Editor

IN deciding whether or not a guided missile is the most efficient weapon for a particular task, the basic question is probably "is the exclusion of man an overall advantage?" The brain of man enjoys a flexibility and adaptability which cannot be matched, or even approached, by any of his own creations. He has a unique degree of independence and can take decisions and assess situations in a manner which no mechanical device has yet been able to match.

From several aspects, in fact, the exclusion of man seems an act of folly. Reasons for such exclusion are in no way connected with sentimentality or fear of operational casualties. Danger is never absent from war, any more than it is from peace. There is still a very good case for the military aeroplane and, in fact, for most of the conventional weapons with which the world's armed forces are at present equipped. Nevertheless, there are operational requirements which can be met more effectively by guided missiles than by anything else which can be foreseen.

Already missiles are showing themselves capable of ousting other weapons from most of the tasks in which a moving target has to be destroyed, irrespective of whether the target is in the air, on land, at sea or under the sea. It is also probable that within a few years—almost certainly less than ten—the world will be faced with the existence of missiles of global range, capable of placing the most destructive nuclear devices on any chosen spot. To meet this fearful threat, work is even going ahead on anti-missile missiles, again proving the truth of the old adage that there is a defence for every weapon.

The Weapons System. Although some Britons find it distasteful, this youthful American term has no counterpart.* It signifies a complete service weapon together with its ancillaries, extraneous components and supporting units, including all equipment needed for storage, transport, maintenance, repair, calibration, testing and training. Missile systems always include the missile itself, some form of launching device, possibly a booster motor for initial acceleration and, in most cases, ground or airborne radar equipment. Many characteristics are common to all missile systems, but much depends on the operational requirements or the type of mission involved.

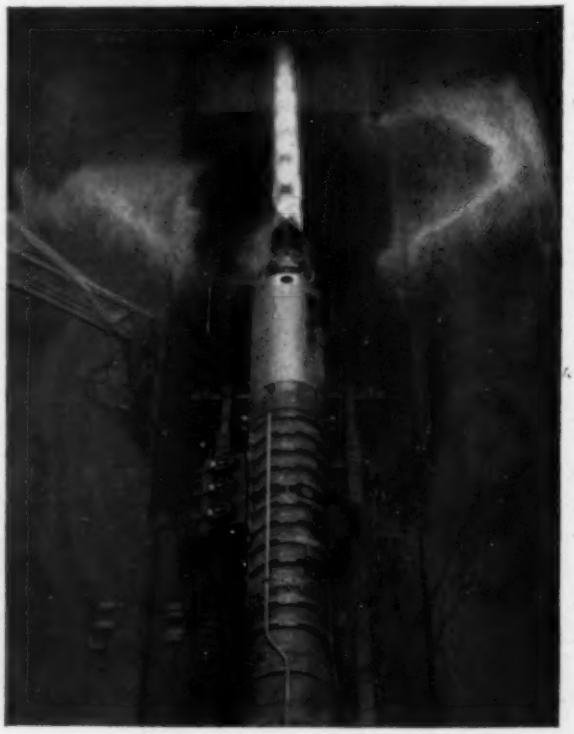
Apart from "offensive" and "defensive," the broadest classification for missiles is that which defines the medium from which they are launched and in which they find their target. As these mediums are "surface," "air" and "underwater," there are nine theoretically possible combinations (such as SAM, surface-to-air missile). This form of classification has been employed in the descriptions—starting on page 893—of missiles at present being developed or in use. In the remainder of this particular account, the emphasis is laid on missiles intended for the destruction of aircraft.

No air force in its right mind would attack a country armed with defensive missiles unless its bombers were extremely fast, high-flying and equipped with the latest detection and countermeasures systems. For this reason the defending missiles are faced with a most difficult task, and a fundamental pre-requisite to their employment is that the whole area to be defended should be covered by a comprehensive and automatic air-defence system.

Such a system is, in the first instance, based upon powerful early-warning radars mounted around the coasts or on piles sunk into the sea or carried aloft in high-flying picket aircraft. These radar installations are charged with the vital task of providing the longest possible warning of any raiding force, together with a rough indication of its scope and character. The second stage of the system comprises tactical-control radars which count the raiding aircraft, determine their speed, altitude and direction, and pin-point actual targets with sufficient accuracy for the final stage. For SAMs, the latter comprises tracking radars associated directly with the missile systems, and it is their job to pick up individual targets for each missile. For AAMs, the final stage is carried aloft in a fighter, although the set may be basically similar to the ground-tracking radar.

Throughout the whole set-up—which may involve a number of allied nations—the keynote is speed; seconds and fractions of a second have assumed a completely new importance. It is no longer merely a matter of using alert and well-trained personnel, for the human factor can be tolerated at no point except to monitor the overall picture; the speed of response of the human brain is

This Crown Copyright photograph shows a firing test on an RTV-2 test vehicle. Points of interest are the massive body construction (tankage) and the shock diamonds in the jet. This rocket motor is operating on liquid propellants (such motors are described on p. 881) and, for the purposes of the test, the cruciform wings and control surfaces have been removed.



*In Britain the term "guided weapon" is sometimes applied to a complete weapons system, the name "guided missile" then being restricted to a missile *per se*. Other terminology is the American colloquialism "bird" to mean any guided missile and the British perpetuation of "round" to describe any individual missile or test vehicle. The adjectives "intelligent" and "hot" are sometimes used to describe vehicles fitted with a guidance system and an internal motor, respectively.

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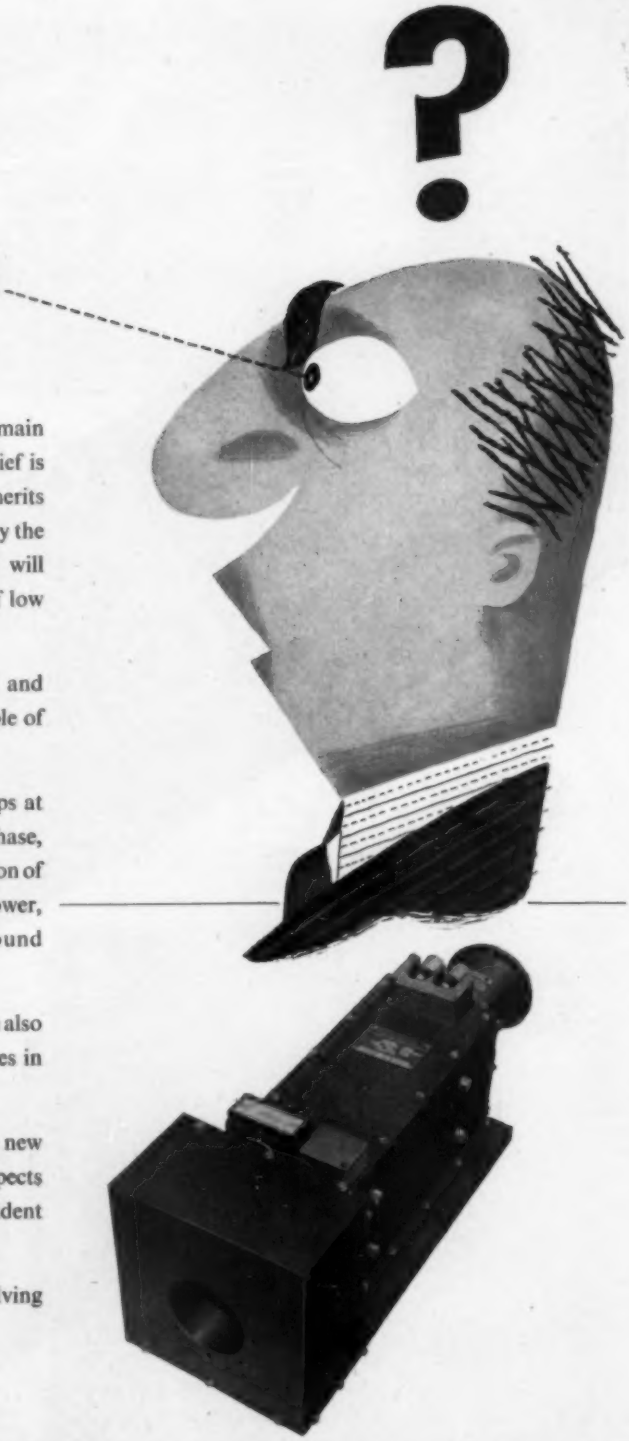

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MISSILES THAT THINK . . .

too slow. In the stirring days of the Battle of Britain, plotters would hold telephones to their ears, watch cathode-ray tube faces and push counters about on maps. Today all data transmission from the early-warning sets is entirely automatic, as is the whole process of feeding information to the second and third stages and to the missiles themselves. In fact, there are grounds for believing that there are air-defence systems already in being which can defend a country though "untouched by hand."

Such a system has to be not only entirely reliable, but it has to make a number of vital provisions which may not immediately be apparent. Some of these are: every target must be engaged by *at least* one SAM or AAM; the total defensive force must be properly distributed among the total raiding force; only just enough must be thrown at each target to ensure its destruction; no SAM tracking set must be able to lock on to a friendly fighter (and, by the same token, no AAM fighter must be able to shoot down either itself or another defending fighter). A further critical factor is that the raiding force must be assumed to bear nuclear weapons, any one of which could create destruction of unparalleled consequence. For this reason every single attacker has to be not only destroyed, but destroyed before it can release what it may be carrying. Means must therefore be provided to guard against unserviceability or any other failure in any part of the air-defence system. The missiles themselves must also be far more reliable than manned aircraft are at present. Statistical approaches are used in the development of weapons to ensure that such a requirement will be met in practice. Statistical reliability study might show that a given target could be destroyed by 1.2 missiles—so in practice two would have to be fired.

The Missile Itself. Some people, including the author, find guided missiles of intense interest. There is much that one can learn from them for, by the nature of things, they are at least one generation ahead of aircraft. Furthermore, their inbuilt intelligence is sometimes of a truly remarkable order and the development effort and workmanship which goes into them is altogether exceptional. It is only unfortunate that their *raison d'être* is at present purely destructive—although missile development has greatly facilitated the design of upper-atmosphere research vehicles and earth satellites.

Basically, a missile is a synthesis of five or six factors. The intangible factor of aerodynamics must be given full weight in the earlier stages of the design, the tangible aspects of structure, guidance and control, propulsion and warhead being the main sub-divisions of the eventual missile. All these factors interact to a degree which surpasses that found in aircraft. Having few traditions, the missile designer is not deterred by a bizarre-looking creation; in fact, it is already clear that guided missiles accept more variety in configuration than do aircraft.

Aerodynamics. The majority of missiles are not purely ballistic rounds but fly with the aid of wings. (At Mach numbers greater than 4, however, it is practicable to generate sufficient lift from the body alone.) Few missile designs are influenced in any way by the requirements of subsonic flight; nearly all current weapons accelerate very rapidly to a high supersonic speed and maintain that speed for the remainder of their existence. It is therefore possible to accept a wing loading several times greater than any admissible in aircraft and the wing can therefore be proportionately smaller (wing loading is determined by the worst combination of the maximum lateral acceleration required at top altitude). Aerodynamic surfaces can be of truly supersonic profile.

Elsewhere in this issue are recounted many of the factors which have to be considered by a missile designer. The author of that article makes it clear that although both birds and aircraft use only one set of wings (placed substantially in the horizontal plane), missiles can manœuvre far more effectively with two sets, mutually perpendicular. It normally makes little difference which part of the missile is uppermost and, in fact, some current designs are deliberately arranged to spin slowly about their longitudinal axis.

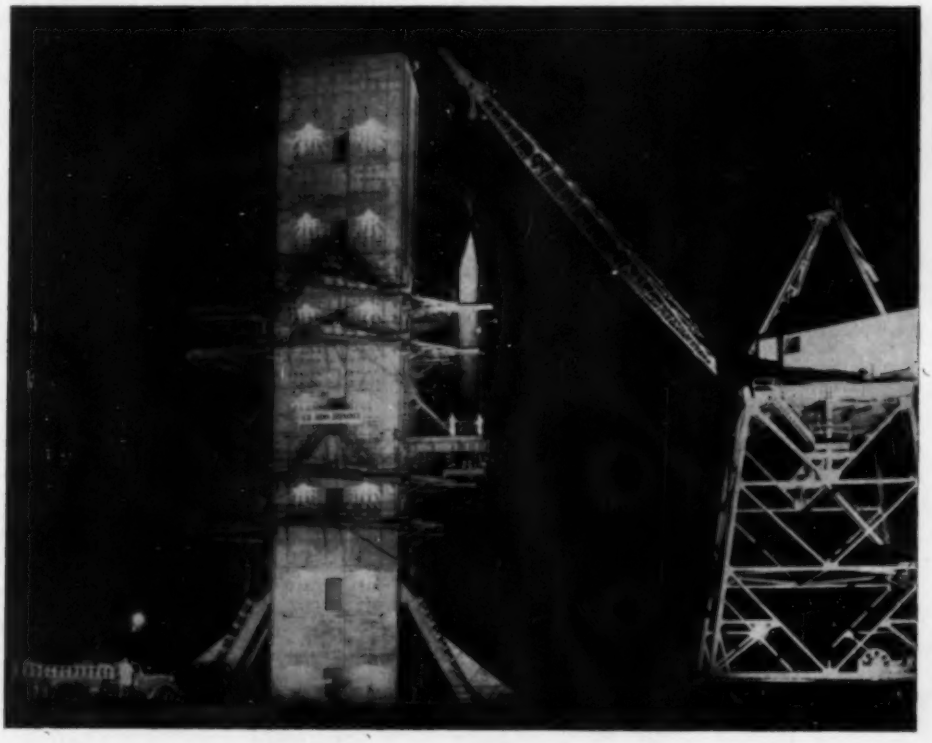
Structure. This is one of the few aspects of missile design upon which it is possible to comment at some length. We have, therefore, reserved this factor as the basis of a special article entitled "Missile Design" on pages 885-889 in this issue.

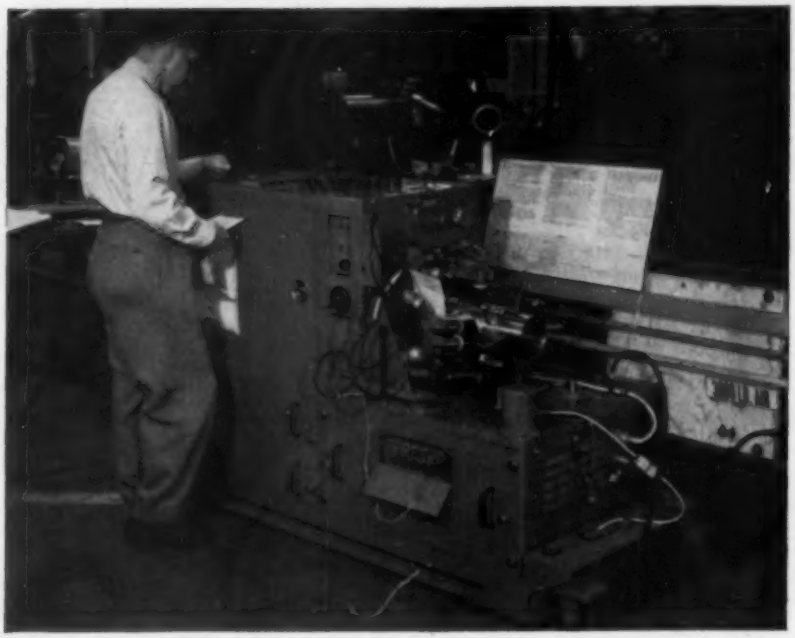
Guidance. There are many who would claim that the development of the guidance system was, in most missiles, responsible for the expenditure of more man-hours than everything else put together. Although not always correct, this belief reflects the very considerable problems involved in making exceedingly complex and densely packed systems function with impeccable reliability, even when subjected to most adverse environmental conditions. There are several types of guidance, which are catalogued below under typical names.

Direct Command Guidance (Fig. 1, p. 880). This is sometimes considered the most elementary form of guidance, since the missile itself has no power of "thinking" whatever. Instead it is steered by instructions transmitted to it by any of several methods.

Typical of the most elementary forms of command guidance is

A Wellsian scene at Redstone Arsenal, a major centre of U.S. Army missile activity. A Jupiter A ballistic weapon is being mounted—by what must be the biggest crane in the missile business—on a vertical rig for night firing. For scale, the Jupiter A is 69ft from nose to tail.





In this photograph the infra-red homing head of a U.S. Navy Sidewinder air-to-air missile is being field tested. The Philco-developed machine carries out 20 tests, and records on the roll held by the engineer. Control-surface torque is countered by the sprung arms which can be seen gripping the cruciform. Typical tests concern caging time, magnetic-amplifier time-constant, cross talk and seeker-head time-constant.

MISSILES THAT THINK...

the arrangement which originated with the German X-4 in 1944 and is perpetuated in such missiles as the French Nord 5200. Information on target position is obtained by visual observation, and the missile is steered by electrical signals transmitted through wires unwound from free-running bobbins carried in the missile as it flies towards its target. Some of the disadvantages are obvious, but the directness of the arrangement has undeniable charm—particularly, perhaps, to designers of more advanced schemes. Furthermore, it cannot be jammed by enemy countermeasures.

Only slightly less crude is direct-command guidance using, instead of wires, a radar link—generally from a transmitter activated by a joystick or miniature control column (in the U.S.A. such a transmitter is termed a "beep-box"). Such a system (Fig. 2) requires a certain degree of piloting skill, together with constant operator-practice. It is widely used for controlling target drones.

Radar Command Guidance (Fig. 3). One step more advanced is the system in which the target is followed by a lock-on tracking radar, information from which is then used to govern the steering instructions transmitted to the missile. A serious drawback is introduced by the inevitable time lag, which allows the target a possible chance of taking evasive action. A pre-requisite to success is that the tracking radar continues to obtain precise information on target position, so that corrective signals can be applied right to the point of interception. The most sophisticated derivative of this system introduces a complete ground computer link capable of working out future positions of the target so that the missile can be steered along a collision course. Such an arrangement is used in Nike.

Beam Rider (Fig. 4). Under this heading are grouped various families of missiles which tend to centre themselves within a pencil beam—with an included angle of about 3 deg—emanating from an aerial near the point of launching. The direction of the beam is so controlled that, irrespective of the time of flight, provided the missile stays in the beam its position will eventually coincide with that of the target. Such an arrangement is really a particular form of command guidance.

Probably the most common system employs a moving beam which tracks the target visually, or follows the movements of a lock-on tracking radar. Another common arrangement is for the beam to be stationary in such a position that the missile is led along a collision course. Normally the beam is coded and rotates so that the missile knows at once if it tends to depart from the centre of the beam, but there are several factors which militate against the effectiveness of the system.

One of the greatest problems is that introduced by imperfections —inevitable in the present state of the art—in the radar, electrical and mechanical equipment. These imperfections combine to produce "jitter"; and the lock-follow circuits are, in any case, governed by reflected radiation which is itself varying and jittering. Further, it is important to note that beam accuracy deteriorates as the distance from the transmitter increases, and is therefore poorest at the target.

Another defect is that the missile is not normally controlled between launching and "gathering" into the pencil guidance beam, and means must be provided to correct the consequent initial dispersion. This is normally effected by providing a second, wide-angle "gathering-beam" with an included angle of at least 40 deg. Furthermore, if the missile has a sustainer motor, the guidance signals contained in the beam may have to pass through the rocket flame before being picked up by the missile's rearward-facing aerials. The variable propagation through the ionization in the flame introduces unwanted disturbances; even an apparently trivial alteration in the chemistry of the rocket motor can make a tremendous difference to the beam reception. In the beam-riding Fireflash the problem does not arise, since no sustainer is fitted.

Semi-Active Homing (Fig. 5). In this system the target is brilliantly illuminated (not, of course, with visible light) by a ground radar and the missile homes on the reflected radiation. The missile's receiver dish is mounted in the nose, looking out in a forward direction. It is free to scan laterally and automatically picks up its target and locks-on. The missile control system then steers the weapon so that it lies directly behind the radar dish, i.e., the missile tends to keep the dish on the centre-line, facing dead ahead. This results in the missile flying a curve of pursuit —a flight-path familiar to all military pilots, and similar to that traced by a dog in response to a call from his master if the latter is himself running across the dog's original path.

In the systems previously considered, the missile aerials have been located towards the rear, either in the trailing edge of the wings or as flush surfaces or spikes projecting from the body. Putting the aerial in the nose at once introduces complications in airframe design. Although the whole nose has to be dielectric it still has to accept extremely high aerodynamic forces and must also withstand flight through rain or hail at perhaps 2,000 m.p.h. Airframe and electronic specialists are in conflict over the question of nose-shape, and the accuracy of the system is impaired by the fact that beam jitter produces variations in the apparent direction of the target.

For example, the maximum intensity of reflected radiation from a large target—like a B-47—may jump from one wing-tip to the other, and then jump to the tail; this is distressing to the missile when the latter has reached close range. Again, the reflected waves entering the missile nose-cone often jump about inside, through reflection or refraction, producing sudden and violent changes in the apparent direction of the target.

On the other hand, any type of homing missile enjoys considerable operational advantages. First, there is no need for the flight of the missile to be monitored in any way since, so long as the target remains illuminated, the missile should strike home.

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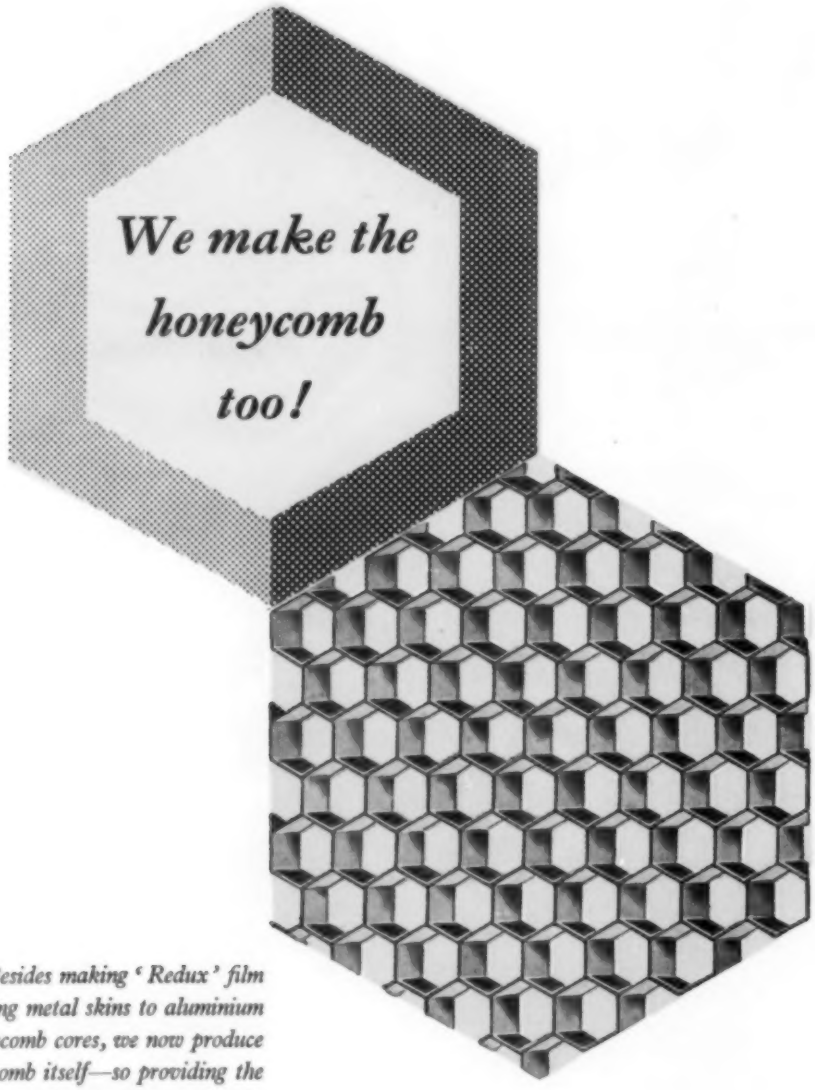

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AP. 264-210

This photograph affords an instructive comparison with that published on p. 878. A Nike Ajax surface-to-air missile is being checked-out in a base-maintenance area of a U.S. Army missile battery defending San Francisco Bay. The saddle unit astride the weapon supplies various electric circuits and microwave radar signals to the diminutive delta projections. The main controls (extreme right) are at full-up deflection.

MISSILES THAT THINK . . .

In addition, as the radar transmitter, or "lamp" set, on the ground can be of extremely high power, the radiation strength can be made intense, particularly when accurate lock-on is combined with a fine pencil beam. Furthermore, the accuracy of the radiation reflected from the target and picked up by the missile increases as the missile closes with its quarry.

Collision-Course Homing. In this system—an offshoot of the above—the receiver aerial is fitted in the nose of the missile and arranged to look out diagonally at a fixed angle. The target is illuminated by a tracking radar on the ground, and the missile aerial picks up reflected radiation. The guidance system then steers the missile so that its "line of sight" course meets that of the target at a constant angle. As Fig. 5 shows, the missile follows a common locus which should take it to the target.

Fully-Active Homing (Fig. 6). This is usually the most complicated airborne guidance system for intercepter missiles. The essential element of such a system is that the weapon generates its own signals and so tends to home on to the target of its own accord, without any external assistance. Any missile which has to be tracked—or whose target has to be tracked—is at a tactical disadvantage, since the number of missiles in the air at any time is strictly limited by the quantity of tracking radars available. On the other hand, a fully active missile has to carry the whole "works" along inside it and so cannot fail to be elaborate, expensive and probably prone to failure. Nevertheless, such missiles are operationally very valuable.

In order to achieve fully active homing with radar, a missile must carry a transmitter capable of emitting signals from a forward-facing aerial, as well as a receiving set and guidance system capable of steering the missile towards the source of the signals reflected from the target. In order to convert the information into steering instructions, the missile must normally carry a complete miniaturized lock-follow set—and, if it is to follow a collision-course path, an airborne computer. This is bound to make the fully-active missile fairly heavy and bulky so that, other things being equal, it must have a relatively short range. In practice, therefore, it may be limited to targets which come fairly close to the point of firing. Another factor is that the radar transmitter cannot be of high power, and its transmission will therefore be more than usually susceptible to jamming.

In view of the strictly limited range of the most powerful set which a missile can at present carry it is often found that the fully-active homing ability can be exploited only at relatively short distances from the target. In many important air-to-air and surface-launched missiles beam-riding is used to bring the missile close to the target, the switch to fully-active starting the terminal phase.

Passive Homing (Fig. 7). In these arrangements the missile homes on some kind of energy or disturbance caused by, or emitted from, the target. Heat, sound, static electricity, magnetic fields, and other systems have been investigated.

Undoubtedly the most important of these systems is the heat homer, sensitive to infra-red radiation. Infra-red is the name given to a band of electro-magnetic wavelengths which are just too long for the human eye to respond to them as it does to visible light. Nevertheless, the wavelengths of I.R. emanations (heat waves) are very much shorter than those of even the latest microwave radar equipment. As a result the resolving power or "clarity of picture" is far better, even if the receiving aerial is very small.

In practice, an I.R. homing head for a missile is designed to function on a chosen wavelength suitable for operational use. This wavelength varies according to the temperature of the target which the missile is to seek out. A typical maximum temperature for a turbojet exhaust is 750 deg C, and the corresponding wavelength is 3 microns. The best photo-conductor capable of responding to such waves is ordinary lead sulphide PbS, and a screen of this material is accordingly inserted as a semi-conductor in the receiver circuit. When the scanner in the missile nose receives any 3-micron radiation it intensifies it and passes it to the receiver-circuit screen, the resistance of which drops and allows a proportional increase in circuit current.

All that the missile guidance system has to do is to maintain the photo-conductor current at a maximum. This is done by making the missile steer towards the greatest source of appropriate radiations which the scanner can pick up. (If the wavelength to which the homing head is sensitive is short enough the missile may try to home on the sun, an unprofitable undertaking.)

As Sidewinder has proved, a complete I.R. homing head can be made very light and compact, and its accuracy approaches perfection as the distance between missile and target becomes zero. There are, however, disadvantages: the missile nose must have a "window" as transparent as possible to the agreed wavelength; the effective range may be seriously curtailed by cloud or smoke; and if the target shuts down its powerplant and then takes evasive action the missile can be fooled completely.

Celestial. This type of guidance is restricted to long-range bombardment missiles intended to hit stationary strategic targets. It really comprises an automatic astro-navigation system. All celestial systems draw their intelligence from a star-tracking telescope capable of locking on to one of the fixed stars. This can be achieved quite easily by radar, or perhaps by infra-red methods. Before launching, the flight path is completely programmed in advance and the required relationship of the missile and the selected star determined for each moment of the journey. The tracking head then holds fast to its star and, *via* a guidance system and autopilot, governs the flight of the missile to keep the star in the correct relative position, making due allowance for the missile's change of position and rotation of the earth.

At ranges greater than about 3,000 miles, or on flights lasting longer than some three hours, it is essential to change from one star to another. The autopilot is also required to keep the missile

MISSILES THAT THINK . . .

Fig. 1. Direct command wire guidance: A, "beep box"; B, wire; C, reel; D, guidance unit.

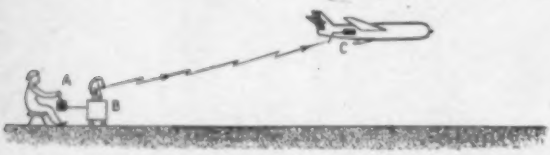


Fig. 2. Direct radar guidance: A, "beep box"; B, radar command set; C, receiver and guidance package.

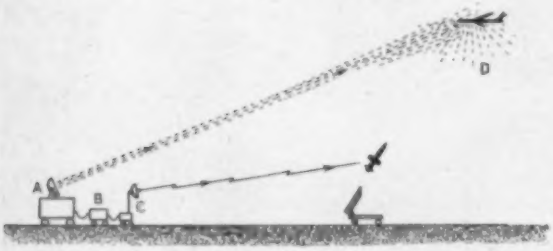
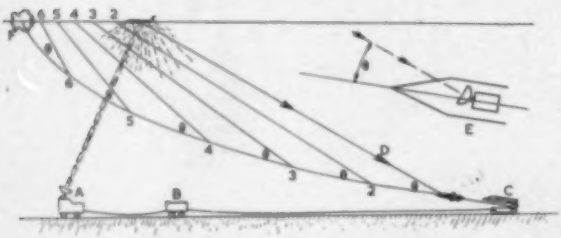


Fig. 3. Radar command guidance: A, lock-on tracking set; B, computer; C, command set; D, reflected radiation from target.

Fig. 4. Beam rider: A, twin radars, one producing a pencil beam directed at the target; B, gathering path in wide-angle radar; C, riding the pencil beam.

Fig. 5. (below) Semi-active homing (collision-course is depicted): A, lock-on "lamp" radar; B, computer; C, launcher; D, return from target; E, enlarged view of homing head; F, position of strike. The numbers are successive positions of missile and target.



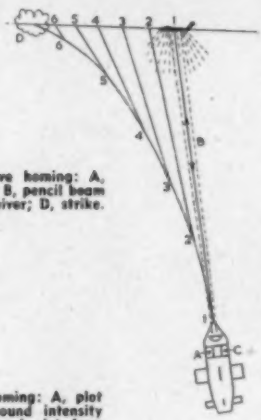


Fig. 6. Fully-active homing: A, radar transmitter; B, pencil beam on target; C, receiver; D, strike.

Fig. 7. Passive homing: A, plot of temperature, sound intensity or other parameter in jet from target; B, radiation from target; C, sensitive receiver in missile; D, guidance system.

on course in the event of the star being obscured for any reason (for example, by high cloud or icing of the tracking-unit window); it is also needed to provide temporary control in turbulent air when the tracking head might be knocked off its target. The missile must also carry a programming unit which, when the star reaches a pre-calculated angle, puts the missile into an optimum dive on to the target by smothering or replacing the signals sent from the tracking head to the autopilot.

Inertial. This is an "ultimate" guidance system fully worthy of the "ultimate weapon," the ICBM. Completely self-contained, it needs no external source of information, neither does it send out any emission which might be detected by the enemy.

Foundation of the whole system is the basic integral calculus. A pre-requisite to the operation of an inertial system is a precise and correct knowledge of the geographical position of the launching point and the target. The missile is fired with this vital information locked up inside it and the inertial system then continuously calculates the speed and direction, and produces steering instructions to ensure that the missile will arrive at the latitude and longitude of the target. This is done by sensing, with extreme accuracy, all accelerations imparted to the missile (sometimes it is possible to ignore accelerations in the vertical plane) and then applying the double integral to determine the distance gone and track followed.

Measurement of the accelerations experienced by the missile are obtained from two or three accelerometers. These must be of extraordinary accuracy, yet capable of measuring an extremely wide range of accelerations, from a maximum of perhaps 10g down to as little as 1/200,000g. Each accelerometer is mounted in one of the missile's major axes, in a gyro-stabilized platform. It is essential that, apart from being sensitive to true linear accelerations, the accelerometers should not be disturbed by other perturbations of the missile. This can be ensured only by tying the gyro-stabilized platform to a pendulum with an effective length equal to the radius of the earth (so that, in effect, the pendulum bob remains at the centre of the earth and is therefore unaffected by movement of the point of suspension). Such a pendulum has a natural period of about 84 minutes, and the inertial-guidance system is accordingly stabilized by an arrangement which simulates the behaviour of a pendulum with such a period.

It will readily be appreciated that errors from an inertial system are cumulative. To reach sufficiently close to a target after a flight of an hour or more demands a standard of accuracy and repeatability of components which is virtually impossible to achieve—it is certainly impossible to manufacture such systems in quantity. Fortunately, it is possible to relax the tolerances, and bring the problems roughly into line with those found in the most precise research laboratories, by employing a hybrid system which is not wholly dependent on information fed in before the start of the flight. Of such hybrid systems, the combined inertial and celestial is perhaps the most popular—it is used in several long-range American missiles—since, although sufficiently accurate and capable of mass production, it remains self-contained, unjammable and undetectable.

Propulsion. There are certain classes of guided missile which have no propulsion at all, the most prolific example of these being the guided bomb which falls freely under its own weight. In addition there are several very important missiles, principally short-range AAMs, which blast through to full speed in from one to three seconds and then discard all their propulsive systems and carry on under their own considerable momentum. Generally, however, some form of internal motor is provided.

Many designs for long-range missiles bear a close resemblance to aircraft. Snark, a U.S.A.F. strategic cruise-type (i.e., non-ballistic) missile is a typical example. Power for such vehicles can be provided by turbojets. The chief requirement for the powerplants is 100-per-cent-dependable operation on one occasion only, and it is possible to make them relatively simple and cheap to manufacture, since they do not have to perform variable-

power running under the wide range of conditions experienced by aircraft. In general, the missile turbojet is operated at constant r.p.m., and requires only a rudimentary fuel system and drives few accessories.

Provided that they do not have to fly higher than about 90,000ft, faster long-range cruise missiles can be most efficiently propelled by ramjets. The modern supersonic ramjet is an attractive prime mover and, since the oxidant is obtained from the atmosphere, the specific fuel consumption is only about one-fifth as great as that of a rocket. Furthermore, a ramjet can be designed to run either on conventional jet fuel or on one of the later so-called chemical fuels with very high heat content per unit weight or bulk. The inherent ramjet drawback of inability to start from rest is readily overcome in a missile by employing a booster rocket.

A typical flight time for a defensive ramjet-missile is 10 to 15 minutes, during which time 300 miles may be covered. It is marginally possible to feed the fuel by air-bottle pressure, and it is more usual to employ a proper fuel pump and control system. Power to drive the fuel pump can be obtained either from a ram-air turbine or from a self-contained powerplant fitted with appropriate automatic regulation. Two extremes of ramjet missiles are the American Navaho, a large and very advanced machine with intercontinental range, and a small French tactical missile with subsonic performance, driven by a ramjet integral with the fuselage.

In spite of the attraction of the above schemes, more than 90 per cent of present missiles are driven by rockets. Such propulsion is invariably the most attractive where the range is less than 30 miles. Rocket motors for missiles are of every conceivable size and character and include units with a greater sustained power-output than anything else yet built—not excepting even the Hoover Dam.

The simplest installations employ solid propellants. By definition, it is not normally possible to pump a solid propellant and it therefore has to be burned *in situ*. For this reason such rockets were originally looked upon as suitable only for booster motors and other applications of short duration. Recently there has been a considerable change in policy, and modern solid rockets are finding wide acceptance in missiles with very respectable range. Moreover, both in Britain and America solid propellants are also being used for the primary propulsion of really large vehicles. Developments are also in hand to feed fuel as strip or tube from a coil.

All solid propellants are finely divided mixtures of fuel and oxidant. In many cases it is possible to employ material akin to cordite. Alternatively the mixture may include a variety of other compounds, including petroleum derivatives. Two of the prime criteria are that the filling should be as dense as possible and burn to form the lightest possible gas with a high jet temperature, low molecular weight and high jet velocity.

A solid rocket is not merely a case stuffed with propellant. The latter is extruded with a cross section (which may be quite complex) suitable for efficient combustion; the area of burning remains constant as the propellant is consumed, so that thrust stays roughly constant. Many years of research have preceded the evolution of the optimum shapes of filling which ignite cleanly and burn without "chugging" or other erratic behaviour. In recent years solid booster motors have been developed either with no casing at all or with a casing which forms part of the propellant or is otherwise consumed. Previously, falling booster cases constituted a potential hazard to friendly life and property.

While combustion is taking place an equilibrium is established between the burning propellant and the resulting hot gas, which renders the process largely self-governing. Reduction of the interior pressure slows down the rate of burning and can even cause combustion to cease; thus, by providing suitable valves in the chamber, it is possible to make a solid motor controllable. Meanwhile, steady improvements in propellants, together with better motor design, have allowed the solid rocket to penetrate fields previously the preserve of the much more complex liquid motor. This has sometimes been accelerated by inability of the liquid motors to meet requirements.

A liquid rocket has to have tanks, feed lines and a combustion chamber, together with an appropriate control and safety system. When the required firing time exceeds about 30 sec it may also be necessary to employ a pump, which necessitates a source of shaft-power. For a motor of 10,000 lb thrust the propellants may have to be fed at 50/lb sec, and to make the whole system foolproof and efficient is very difficult, in view of the environmental conditions to which a missile is subjected.

In recent years, however, much has been done to ease the problems of complexity and unreliability which have plagued many of the earlier liquid motors. For many missile applications it is possible to use an uncooled chamber with a suitable type of refractory lining. Furthermore, ingenious ways of surmounting the problems of fuel systems are now bearing fruit. As an example it is possible to cite the British K.P.4 motor, in which fuel is housed in cylindrical tubes and fed to the motor by free pistons moved by gas pressure. A single chamber might be fed by six tubes of liquid oxygen and one of hydrocarbon fuel.

Warhead. Of all the aspects of guided weapons, that most subject to stringent security is the joint factor of warheads and fuzing. Nevertheless a few notes are admissible.

Fuzing is most commonly of the proximity type. Such devices were first developed in 1944 and trigger the warhead either when the missile approaches within a specified critical distance of its target or when it reaches its nearest point. At launching the missile is "safe" and the fuzing is armed during flight. In a typical anti-aircraft system the fuzing system emits radar signals which are reflected from the target. So long as the return signal strength goes on increasing, the armed warhead is left alone; but the moment the rate-of-increase of signal strength becomes zero (as it does when the missile reaches its nearest point to the target) the charge is triggered. This holds good even if the miss-distance is as much as a mile. Of course, the warhead would also be triggered by a direct hit.

The greatest allowable miss-distance depends on the size of charge and the accuracy of the weapon. If guidance is good (fully-active homing, for example) the required miss-distance can be quite low—perhaps only 10 or 20ft. Conversely, the poorer the guidance, the greater must be the proximity-fuse miss-distance and the larger must be the warhead.

Apart from nuclear devices, which are a special case, most anti-aircraft missile warheads depend for their effect entirely on fragmentation. Blast, even from a heavy charge, has a very limited lethal radius. There is, of course, an optimum fragment size. If the splinters are too big there will not be enough of them to ensure that the target is vitally hit; if too small they will lose energy too soon and fail to penetrate. It has not been found easy to achieve this optimum size. A recent American report described a relatively simple means of doing so; the warhead is wrapped in windings composed of "optimum fragments" threaded on nylon cord.

Accessory Systems. Engineers responsible for developing any components required for supersonic aircraft have now learned that the problems posed by sustained supersonic flight demand a wholly new approach to design. In some respects the requirements of a missile component are less arduous. Flight-time is invariably much shorter and, except for two or three seconds of fierce initial acceleration, the entire flight takes place at more or less constant supersonic speed. Nevertheless, most design-considerations are adverse:—

Space: Volume must be minimized, requirements in this respect being more stringent than in any type of aircraft. It is rarely possible to accommodate any item larger than a 6in-cube in a short-range weapon.

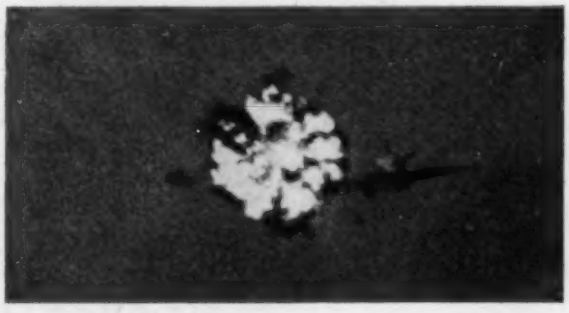
Weight: This also must be minimized and integrated with the equipment disposition to produce the correct c.g. position. In the typical SAM, 5 lb of additional weight may reduce the range by a mile.

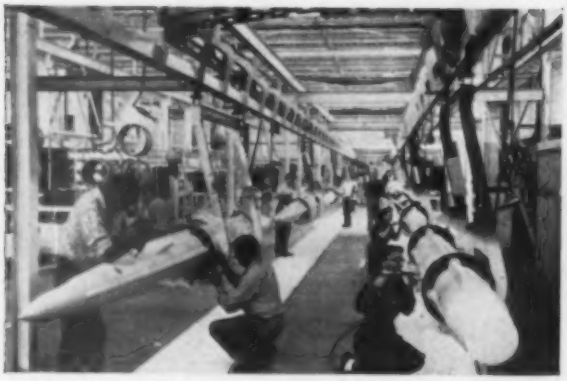
Vibration: This may well be of extreme severity. Irrespective of the type of propulsion, the combination of extreme thrust, very high velocity, aeroelasticity and small overall weight can result in high-frequency oscillation with an amplitude clearly visible to the eye.

Acceleration: To state that the whole missile has to resist 40g gives little concept of what is involved. Nobody would reasonably expect a television set to work after being thrown out of a third-floor window, but the more complex interior of a missile could withstand such treatment as a matter of course. It is interesting to note that American workers have found sled-testing invaluable. Components which pass all vibration tests have frequently been found to fail under sustained acceleration on a sled.

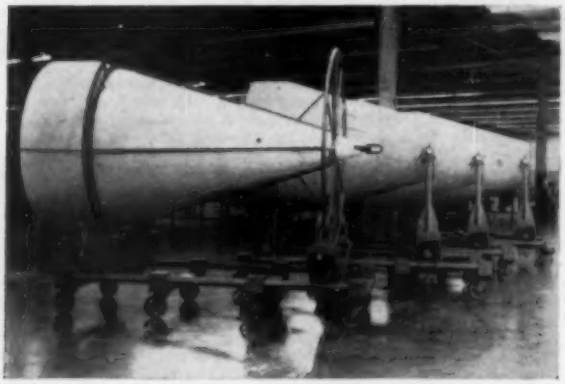
Temperature: Limits of −50 and +300 deg C might be met by different parts of a missile, but in weapons of fairly short range thermal lag may ease the extreme interior conditions. Neverthe-

As described at the top of the column above, missile warheads are arranged to be detonated by a proximity fuse at the nearest point to the target of the weapon's path. Here, a Fireflash is exploded at an appropriate miss-distance from a Firefly.



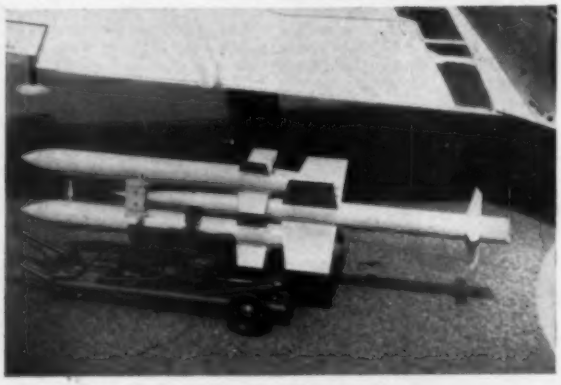


Many thousands of missiles have been made by the Santa Monica division of the Douglas Aircraft Company. This overhead conveyor line takes Nike Ajax weapons through final assembly.



Compared with the picture on the left this view of a bay in the Chrysler plant in Detroit emphasizes that big missiles come in smaller numbers. These are warheads for Redstone (Jupiter A).

Thoroughly covered in frost, this Canadian Velvet Glove air-to-air weapon is roughing it in the Westinghouse plant at Hamilton, Ontario, after a test at —100 deg F at a pressure equivalent to 95,000ft.



Sole British guided weapon of which photographs may be published is the Fairey Fireflash. This fluorescent-red-painted example is seen on its transport and lifting (by manual screw-jacks) trolley.

MISSILES THAT THINK . . .

less, many components will invariably get hot enough to fry an egg or even melt solder.

Air Pressure: Static pressure may drop from atmospheric to less than 1 lb/sq in in a period measured in seconds; and in three or four seconds the dynamic head may jump from zero to perhaps 550 lb/sq in.

In general, the missile accessory business parallels that which supports the development and production of aircraft. Each complete weapon contract is tied up between the purchaser or sponsor (the Ministry of Supply in Britain) and the main contractor. The latter—probably an aircraft or electronic firm with an appreciable experience of such work—investigates the mathematics of the requirement and comes up with an initial design study. Probably at a fairly early stage are the accessory manufacturers brought in. Each is given a fairly comprehensive specification underlining the conditions under which their parts will operate, but it is unlikely that they will be told full details of the programme or any information not concerning them directly. The accessory maker must, however, say what his part will weigh and how big it will be; and, having committed himself, he must adhere to his estimate, since redesign at a late stage may be disastrous in its results.

Most careful attention must be paid to material specifications. Not only must every part be fully capable of standing up to the extremes of temperature and vibration, but all components must be mutually compatible—there must not, for example, be any trouble from differential rates of expansion. It may be possible to evolve items from units originally designed for aircraft, but fundamental changes may be necessary. Mechanical strength may need to be increased, and the rigidity of movable or cantilever parts may need to be increased, to take the natural frequency out of the vibratory ranges experienced and thereby prevent resonance.

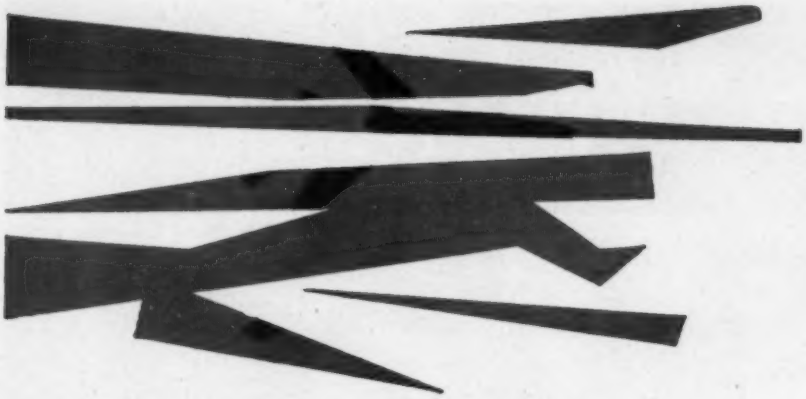
To take a particularly simple case, it is frequently found that a simple potentiometer for a piloted aircraft can be made from what might be termed "traditional" materials. The winding can be based on a plastic former, and if any turns have to be blanked off this can be done readily enough by attaching a strip of wire to the required turns with ordinary soft solder. For missile use several changes would have to be made to such a unit. The former for the coil-winding would have to be of ceramic material, resistant to high temperatures. For the same reason, something would have to replace the soft solder; and any input or output wires would have to be insulated with glass beads and not with rubber or other conventional substance. Even the potentiometer wiper-arm would have to be redesigned, and made stronger—so that it could bear high accelerations—and stiffer—so that it could not resonate in sympathy with a missile natural-frequency.

Once the basic design appears to be correct, the standard development procedure can be applied. If the item is fairly complex six prototypes may be made and thoroughly proved, and a suitably modified unit may then be submitted to the prime contractor for full laboratory checking. Even if the component is eliminated through some failing, it may well find its way into the missile-system ground equipment (which is an even bigger field than designing for missiles themselves, and one with a largely different set of problems).

Power Systems. Nearly all the accessory power needed by a missile can be provided by any of four systems: stored electricity, air or gas bottles or gas from a slow-burning charge, ram-air or a self-contained source.

Electrical accumulators provide power in the form in which much of it is required. A direct-current system can, in fact, supply direct pick-offs for telemetering signals. An a.c. system may be more miniaturized but output amplification may be required. The accumulators are normally arranged in potted, shock-resistant banks, each cell having a very high capacity for its weight or bulk. A recent development is the self-activated, chemically-heated battery. A recent American example, weighing 10 oz and fitting a 2in cube, gives 25 amp at 9 V; it has an established shelf life of a year.

[*Cont. on p. 883*



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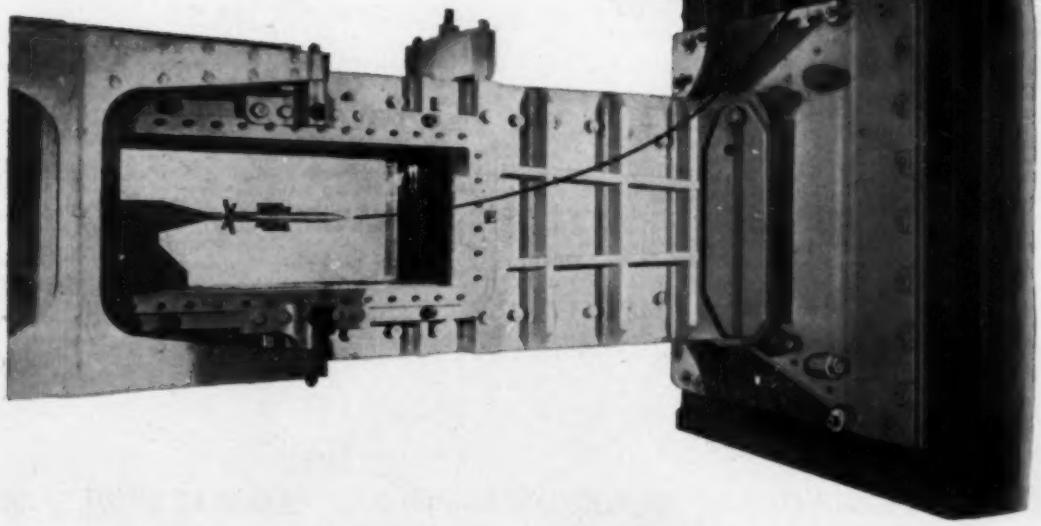

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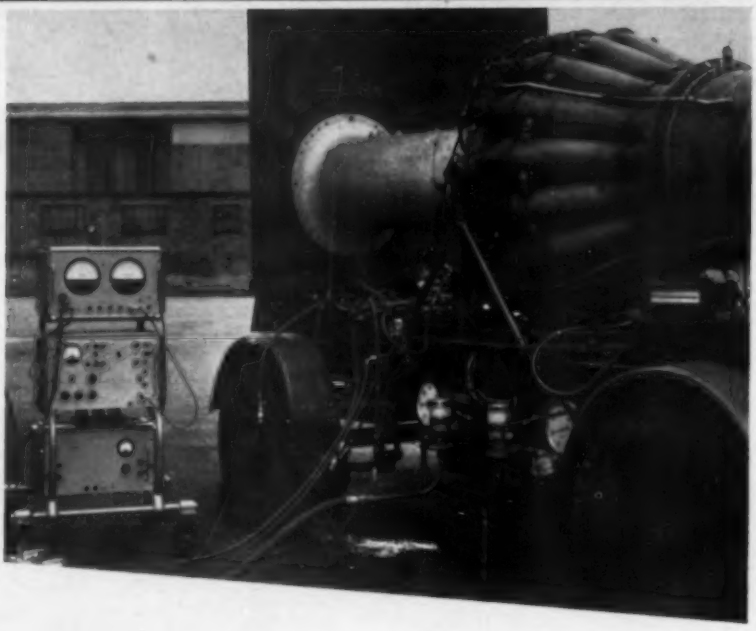

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MISSILES THAT THINK . . .

Stored air or other gas is held, at a pressure which may be greater than 5,000 lb/sq in, in any of a variety of forms of bottle. It has frequently been found that toroidal (ring-shaped) pressure vessels have to be adopted, not on the grounds of efficiency but because it may be impossible to fit a sphere into a missile. The feed-line leads through a pressure-reducing valve which regulates the delivery to a moderate pressure suitable for various services. This pressure can be held constant as the pressure in the bottle falls, and the circuit is so designed that the pressure remaining in the bottle does not fall below the level from the reducing valve within the flight-endurance of the weapon. Several missiles employ pneumatic shaft power. Bendix, for example, produce a pneumatic-vane motor driving an alternator and hydraulic pump for the control system: data are 1.5 lb, 2.75 h.p. at 100 lb/sq in and limits of −20/+120 deg F and 60g.

Slow-burning charges are widely used in missiles as sources of high-pressure gas. The charge, of any suitable material such as a solid rocket propellant, is housed in a cylinder and ignited electrically at the firing of the missile. The combustion is stabilized automatically by the balance of gas pressure and rate of combustion, and the resulting gas-output is filtered and controlled for useful purposes. The British K.P.4 rocket motor is fed with liquid fuel under pressure from such a system and English Electric have developed complete accessory power packs energized by such combustion.

Ram-air systems can provide appreciable power for a low installed weight, irrespective of the duration required. They are therefore suitable for weapons designed to fly at high supersonic speed for an appreciable period at a height not greater than about 90,000ft. Such requirements are appropriate to ramjet missiles and it is quite common to find a ram-air turbine driving a ramjet fuel pump and providing accessory power. As the fuel pump normally absorbs most of the shaft-power generated, it is fortunate that the fuel-flow required falls off in the same proportion as the ram-pressure as altitude is gained. A disadvantage is that systems powered by ram-air may have to be initially energized by some different means immediately before launching.

Among self-contained power sources the most widely used are those in which a tiny turbine is spun by what is actually a rocket motor; the latter can burn any of the fuels normally employed in rocketry. Today it is possible to draw as much as 50 s.h.p. from a unit which, even with tanks, valves, control system and other appurtanences, is smaller than a typewriter.

No information has been released on British equipment of this type, but many varieties have been reported from America. Whirlajet Inc., make solid-rocket units arranged like Hero's turbine in sizes from ¼ h.p. to 20 h.p. A typical unit, running at 12,000 r.p.m., drives a hydraulic gear pump and a 2,500-Watt d.c. generator with commutator. AiResearch make a variety of missile A.P.Us. running on solid or liquid fuel. A typical 29 lb unit has a single shaft running at 24,000 r.p.m. with a single-stage turbine at one end and, at the other, a 2.5 h.p. hydraulic pump and/or an induction generator rated at 650 W (overload 1,600). A.M.F.'s turbo engineering department have also evolved environment-free power packages based on turbines driven by hot air or controlled rocket combustion. Several patterns are available, rated at up to 35 h.p. with electrical or hydraulic output. Adel also make self-contained electro-hydraulic packages for use in missiles.

Several firms have developed hydraulic systems for operation at 450 to 480 deg F and other companies—notably G.E.—are in production with complete electronic systems (valves, transformers, capacitors, resistors and motors) capable of use at the remarkable temperature of 500 deg C.

It is sometimes possible to use the energy from controlled mono-propellant combustion directly. An example of available equipment is an American missile-surface pulser for step functions. Power is drawn from fifty 0.22in cartridges driving opposed pistons, swash plates and an output shaft. At a surface deflection of 20 deg the torque generated is 250 lb-in, and higher values are achieved with longer cartridges. It is possible to adjust the amplitude, duration and spacing of successive square-wave pulses.

Taken last July, this photograph depicts a Boeing QB-17 drone about to be killed by a GAR-1 Falcon fired from an F-102A intercepter. The Falcon caught the drone in the fin (foot of page).

In short-duration weapons recourse is frequently made to "run-down" mechanisms. Gyros may be spun up before launching and left without-energization during flight. It is also worth noting that various types of stored mechanical energy, both from conventional springs and other systems, are finding missile applications.

Miscellaneous: The following are some of the many factors in which problems are being found in the development of missile equipment:—

De-icing. Curiously, many missiles require to be de-iced. In several, provision is made to heat the interior by hot air before launching in sub-zero conditions. This is perhaps the easiest method with a 70ft ballistic weapon or a large SAM elevated to a high angle. One American artillery-type missile is completely shrouded by a G.E. electric blanket before firing.

AAMs are, of course, invariably cold-soaked at high altitude before being called upon to perform their life's work with absolute reliability. It is difficult to cosset such a weapon in the manner of Honest John but airframe de-icing can be carried out by such a system as Napier's Spraymat—which has already been successfully evaluated on RTVs. Furthermore, it is often necessary to feed the missile with hot air—to keep an infra-red photocell at the correct temperature, for example—and with cold air, which may be needed to cool the electronics (which have to be operating before the missile is fired).

Filters. In several missiles there is a need for extreme purity in the working fluids, and a complete absence of foreign matter is essential where tiny bearings or metering orifices are involved. An example is the porous stainless-steel filter (Poroloy) used in the 3,000 lb/sq in air-line to Corporal's air tank.

Bearings. Present bearings are hard-put to withstand ambient temperatures exceeding 250 deg F. Although thermal lag and clever insulation is staving off the evil day, there is no doubt that this limit must eventually be pushed to at least 1,000 deg F. Possible solutions are the employment of new bearing materials, like graphite or various ceramics, and the introduction of completely new lubricants like molten sodium, powdered graphite, steam or even air. This is one of the major problems in the development of the intercontinental ballistic missile.

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REFLECTIONS OF A WEAPONEER

Some Thoughts on Missile Development and Production

By B. A. HUNN, B.Sc.

IT is only during the last year or so that guided weapons have shown signs of progressing from the experimental to the production stage. In parallel with this progression, the ideas of the engineers engaged on their development have changed correspondingly. During the experimental stage, many of these ideas resembled folklore—based on experience and prejudice from other fields employing similar basic techniques. It is safe to say that folklore has now given way to reasoned argument based on precedent, in so far as the individual engineer is concerned, and that the industry, in the corporate sense, is rapidly following suit.

Reminiscing can be an odious pastime, particularly when it involves a collection of V-bomb stories; but, like most other people, I had my earliest contact with guided weapons on the advent of the V.1. First impressions, apart from fear, were that the device was most effective and almost invulnerable; it was obviously comparatively cheap and appeared to have enormous possibilities which would need little time to develop. We were shortly to realize that the V.1 was an inaccurate device suitable only for indiscriminate bombing, and that the most effective (existing) defence was the courage of the intended victims.

As a member of A.A. Command, I was able to appreciate the defence problem and, in particular, the significance of the time factors involved. The operation against each V.1 required detection, position-finding, prediction, data transmission, gunlaying and (if proximity fuses were not used) fuse-setting, all of which occupied a finite time. It was obvious that the composite time had to be brought within the limits dictated by the early-warning range, which was short by reason of the low-altitude weapon trajectory. Astonishing success was achieved with a heterogeneous mixture of equipment integrated into a defence screen on the East Coast, and one could not help reflecting how much better the screen could have been had it been designed at the outset as a complete weapon-system.

While the V.1 filled one with grudging admiration, the V.2 seemed to be the penultimate as an aerial bombardment weapon. Reflections on the type of defence required to meet this threat suggested one which depended upon an integrated system employing some elements of what is now called automation, to minimize the time element; parabolic prediction of future position; and the use of sufficient numbers of unguided rockets to set up a barrage with a high kill probability. Subsequent experience with the early radar used against the V.2 cast grave doubts upon the second assumption. The best that could be said at the time was that the parabolic predictor provided an early warning of the general area of attack. Two recollections of this period stand out. The first is the fact that even with a high-power radar there were certain portions of the V.2 trajectory where the aspect of the missile presented to the radar was insufficient to give an adequate signal strength to retain lock. The second is that a number of V.2s became prematures, due presumably to kinetic heating effects. Finally, the subsequent arrival of the atomic bomb made it obvious in 1946 that a combination of a nuclear warhead and V.2 type of weapon would be decisive in all future wars.

After the end of the Japanese war it was suggested that, had the conflict with Germany been prolonged for a few months, then we must surely have lost. This argument was based on reports and specifications of the full weapons armoury that was being developed in Germany at the time. It was inferred that ground-to-air and air-to-air weapons were within six months of completion, and that, had they been used, all enemy aircraft over their country would have been destroyed. The sudden unexpected attacks with V.1 and V.2 tended to encourage belief in these reports. In my case this view was to be somewhat modified.

This phase of my career was entirely at the receiving end, but some years later I responded to the glamorous call of the guided-weapons industry to look at the problem from the other side. During the intervening years I had tried to convince myself that guided weapons for anti-aircraft defence were not as effective as some suggested, because they might tend to interfere with one another when fired in large numbers. One can presumably ascribe this to the subconscious belief that one should build relatively inaccurate missiles and fire numbers of them at one target. In this new capacity I was taught to believe in the rôle of the large and lethal "one-shot" weapon; but I still hope to see a compromise between the anti-aircraft-gun barrage and such large missiles.

My approach to the industry was coloured by the past. The Germans must have started work on guided weapons nearly ten years earlier, and I believed that we should be able to progress quickly. It seemed quite clear that the problems were almost exclusively technical, and that if they were given to a small but balanced and inventive team of scientists the answers could be rapidly produced. Once the answers had been conceived then the job was nine-tenths done, and one could therefore surely expect a whole host of new principles and ideas in this brand-new industry. Such was my initial approach.

After a while it became sombrely clear that the problems of introducing guided weapons into service were not only technical but also economic, administrative and educational. Because they are more tangible, the technical ones now seem the easiest. The economic problems are important because each project involves not only financial burdens but also a drain on manpower, disturbing the balance amongst the related industries. The administrative one is derived from the need to organize industry to design, produce, test and generally handle missiles. The need to use large quantities of semi-skilled labour which requires some training forms the basic educational problem.

Impatience with slow progress is a characteristic of youth, and this usually manifests itself in one of two ways. The negative approach is to sit back and do nothing in the face of frustrating apparent inertia. The positive approach uses initiative to cut red tape and cross the procedures painfully evolved by a long-suffering management. "Slow" is a relative term, and one has to consider the relation in which it is used. In this context it is the speed of technical progress in relation to that expected by the young scientist—he fails to appreciate that ships in convoy must travel at the speed of the slowest and that the "convoy" is an extremely complex industry which must learn as it proceeds. I must confess to having been one of these youthful enthusiasts.

Team Organization

With respect to the organization of the composite team referred to earlier, it is not sufficient to gather together various groups of specialists and expect a team to result. It is essential that each specialist has an adequate appreciation of every aspect of the job in hand, so that no particular art is emphasized at the expense of the others. Finding the correct balance in any team is quite difficult and depends to a great extent upon the nature of the projects undertaken. I had believed that a team based upon graduate physicists would sort itself out, but it seems that the industry would benefit from fewer scientists and more good engineers, although the latter are in some respects less adaptable. Nevertheless, science and technology should not be unduly devalued, for they have a vital part to play. Good design depends upon an adequate regard of all relevant factors. Knowledge of these factors is available when established techniques are used, but in nine cases out of ten the theorist looks for new techniques which introduce factors undisclosed at the initial design stage. While this tendency must be allowed full rein, it must be appreciated that it is inimical to a contracted time scale.

At one time it seemed to be an eminently sensible idea that industry could best be trained by feeding to it many projects, few of which would ever reach fruition. Only design teams are now trained this way; and, since they represent the brains, the rest of the body must be exercised if an effective and healthy industry is to emerge. It is apparent that the best way of extracting reliable production and satisfactory design techniques from industry is to put a number of projects into service. Development of a weapon virtually starts when it is handed to the users, and it probably requires thereafter five to ten years for completion, as is the case with nearly all new devices.

For some years past the idea of "push-button warfare" has been freely bandied about. This conception once held an appeal which has now largely evaporated. Automation on the battlefield is rather pointless unless applied with discrimination, for reliable machines are fairly predictable in any given situation, whereas there is nothing less predictable than the human being. If surprise is the keynote of victory then the human being can never relinquish command of the situation. For this reason I believe that there is a great field of application for the tactical weapon. So many people in the past have striven for the gun that shoots round corners—yet it has already arrived, in the form of a guided weapon.

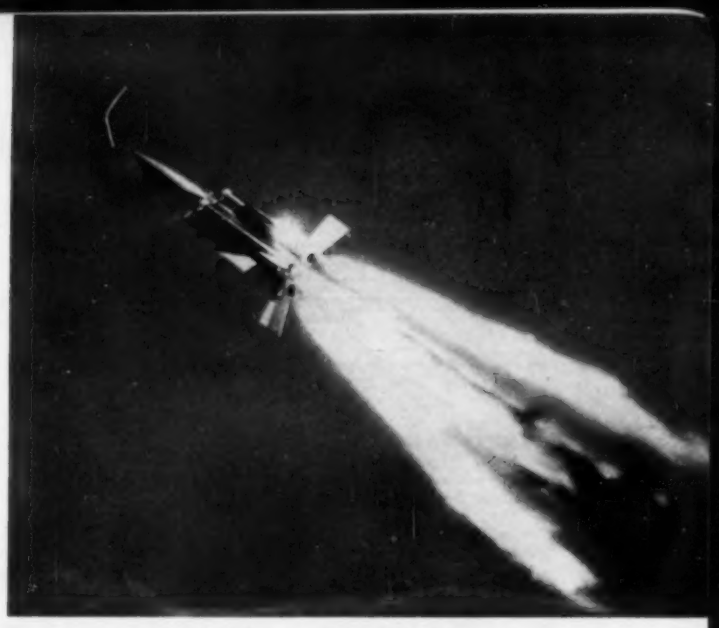
What of the future? Even now there are signs that the public are more preoccupied with present material comfort than with future security. Should we stop devising more and more complex weapons, or should we continue in the hope that some benefit to mankind will ultimately emerge? If it does not, will the history of the inter-war years repeat itself?

I believe that the answer is that we must continue to develop new weapon techniques. It would be surprising if these techniques do not in due course find peaceful applications, thus helping to secure both the military and economic future of this country.

MISSILE DESIGN

The State of the Art

By PETER J. FARMER, A.F.R.Ae.S.



An English Electric missile in boosted flight.

AS an exercise in aeronautical design guided weapons present the most complex problems. Proposals for the construction of complex self-propelled weapons—both guided and unguided—are as old as those for aircraft; but it is only within the last decade that all the associated techniques have reached a level of maturity that make practical realization of such weapons possible. Even today, although weapons such as Nike are installed as part of the air defence system of United States cities, doubts are expressed as to their true effectiveness against the most modern of high-performance bombers; and it is probably more realistic to regard such weapons as training equipment to accustom the armed forces to their tactical use and familiarize them with the logistic problems involved.

In the design of a guided weapon it is necessary to synthesize the most advanced knowledge in the well-established aeronautical arts of structures and aerodynamics with the more recently acquired practice of rocket-motor or ramjet design, and with the techniques—principally developed in their own right for other industrial purposes—of electronics and servo-control. Undoubtedly the latter are responsible for most of the more severe problems which stand in the way of the reliable operation of the present generation of guided weapons. They are respectively identified as "guidance" and "control."

It is not proposed here to discuss the intricacies of these systems, other than to indicate why, from considerations of the overall design, they do represent the major problems.

From most aspects—for instance, performance, handling, rate-of-fire and structural efficiency—it is essential that the final weapon be as small and light as possible (i.e., the perennial design problem experienced with aircraft). In addition, to aggravate the design situation further, the equipment installed in a missile must possess a high operational efficiency, coupled with the requirement that it shall work consistently and immediately on demand, even when subjected to high rates of acceleration, after a prolonged inactive life in store. High efficiency and low weight are never immediately compatible. Operational axial accelerations as high as 40g have been quoted, and these must be considered in conjunction with simultaneous lateral accelerations of the order of 12g and upwards.

The advent of the transistor provides a potential solution to one of the more formidable electronic problems. Before transistors became available severe troubles had been experienced with the thermionic valves under the harsh conditions experienced. Nevertheless, another, and more obdurate, electronic problem still exists. An effective guidance system must not be susceptible to enemy jamming or interference. With bombardment missiles it may be possible to monitor the flight path, using natural phenomena (such as observations of stars) to obtain fixes and courses to steer. These observations cannot easily be upset by the enemy.

Interference with defensive missiles, which are required to intercept an enemy aircraft (or missile), is relatively more simple, especially when it is known what characteristic physical signal is being utilized for guidance. Such signals may be reflected radar (pulse or continuous-wave), "locked-on" radar beams, or infra-red or acoustic energy emitted from the target. Spurious signals can then be generated by scattering "window" in the case of radar, or by providing false sources of heat or noise.

Servo-control problems are equally difficult because of the mechanical aspects involved. Until the requirement for guided weapons arose there was no ultra-light servo system capable of generating the requisite power at an acceptably high frequency of operation. The manufacture of large numbers of components for such servo systems, with precisely repeatable operational characteristics, is likely to be one of the major difficulties. If each example of a particular servo system has to be hand-built and individually adjusted the operational value of the weapon in which it is fitted will be severely restricted.

In air-to-air missiles these servo systems are likely to be pneumatic, but for ground-to-air weapons—which have a longer operational life—it may be advantageous to achieve minimum weight by using a hydraulic system. In the case of short-duration pneumatic systems, energy to operate the servo controls can be provided by compressed air stored in bottles. For hydraulic systems, and pneumatic systems with a longer operational life, power can be obtained from gas pressure obtained by burning cordite under controlled conditions.

These two aspects of the design problem, servo control and guidance—although admittedly the most severe—emphasize the advanced level of technical and theoretical skills required in all branches of the relevant applied sciences before a design is even attempted.

To make such knowledge available it has been the practice for several major industrial organizations—one of which is designated the "principal contractor," to collaborate on the design of each weapon. As guided-weapon technology was at first considered to be an extension of the art of aircraft design the principal contractor was usually chosen from the ranks of the aircraft manufacturers. As a result of the early experience obtained, and the consequent better appreciation of where the main problems lie, a new trend is now discernible. Today, the company chosen as principal contractor is often an electronics firm; it is responsible for the servo control or guidance system, the aerodynamics, structure, warhead and propulsion being considered to be subsidiary problems.

But, subsidiary or not, the latter are the only aspects of g.w. design about which it is possible to conjecture and draw general conclusions as a result of studying the photographs of the vehicles and weapons that have been published to date. In this country, public information relating to g.w. design is nebulous, and this in itself may be construed as indicating that progress has been neither as fast nor as successful as originally expected.

As in all aeronautical design problems, the starting point is the estimate of the final gross weight. With a new aircraft design this can be assessed with a fair degree of accuracy after correlation of the known figures for existing aircraft of similar pattern. For the first guided weapons there was little suitable quantitative information available, and the weight must have been a "guesstimate" in the true sense of the word—which probably accounts for the large number of abandoned designs and studies among the plethora of early projects in the U.S.A. Even today it must still be a difficult proposition to evaluate the final weight of a projected new design, and many guided weapons in an advanced state of development must be deficient in performance because of realized discrepancies between the estimated and actual launching weights.

It is likely that the estimated weights will be lower than the realized figure because, in the marginal state of the art, pessimistic assumed weight values would condemn the project in the design-study stage by making it impossible to attain the desired minimum performance. One of the disconcerting, but nevertheless consistent, factors of design is that the gross weight tends to increase as the project develops; and in the initial estimating this has to be balanced against the amount by which it is hoped to reduce the weight of individual components as a result of development. Owing to the fact that all the equipment installed in a guided weapon is usually developed rapidly and concurrently, the accuracy of these initial estimates is generally poor. Even the hope that the under-estimated weights will be cancelled out by the over-estimated is poor consolation, because it usually involves a shift in the position of the centre of gravity of the completed weapon, with a consequent risk of impairing perform-

Fig. 1. Aircraft need to bank in order to provide a lift-component for a turn. A cruciform-wing missile can generate a lift force directly in any required direction.

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ance by adversely affecting the inherent stability. Weight analysis must also be more detailed than in aircraft design, and ounces and even fractions of an ounce are important. One consequence is that production items such as castings must be particularly closely controlled, since such components tend to become heavier as production proceeds, and the margin of permissible weight variation for individual parts is small.

Another critical factor that must loom large in the initial design stage is the allocation of space. The total volume of the missile is determined by the amount of equipment it is required to carry. Too large a volume means higher drag, heavier structure and greater pitching or rolling inertia, with a consequent reduction in performance. Too small a volume means, at worst, inability of the weapon to meet its specification; at best, some item has to be drastically pared, to provide room for what is absolutely essential. Thus it might be possible to reduce the size of the warhead, although this inevitably reduces the operational value of the weapon. It follows that the initial specification for a guided weapon—and the initial design concept to meet this specification—must be most carefully determined, because all aspects of the design are more closely integrated than is the case with an aircraft. Any major miscalculation at the initial planning stage, requiring a design modification at a later stage, is almost bound to have a serious effect on the final performance, even if it does not cause the design to be abandoned. Guided weapons are not, therefore, so amenable to "stretching" as are most contemporary aircraft designs. Whereas additional "black boxes" can generally be incorporated in a developing aircraft, this is impossible with a guided weapon unless envisaged in the initial concept. Volume packing densities often exceed 50 lb/cu ft. Space and weight are thus two of the factors which confine g.w. design with extreme stringency.

As aircraft conform to a general geometry, dependent upon their rôle, so do guided weapons. There are two methods of manœuvring the missile along the desired flight path.

One mode of achieving a change in direction is to bank the weapon and apply control loads in a manner similar to that used in conventional aircraft. This system is relatively slow in response, and so is suitable only for weapons flying a predetermined path where the most rapid manœuvres are not required. The resulting "aircraft-type" configuration is usually specified only for bombardment weapons, and even for these the configuration merely represents an interim stage until the true ballistic missile has been evolved.

Where high rate of manœuvre is paramount, as it is for defensive weapons which have to intercept agile and fast-moving targets, a different missile geometry was very quickly (and almost universally) adopted, involving a cruciform layout with double pairs of wings and control surfaces. The virtue of this arrangement is that, by movement of the appropriate controls, a force can be generated in the required direction as a component of the lifts induced on each mutually perpendicular wing pair. This can be done in the minimum time, and without first having to twist or roll the missile about its longitudinal axis.

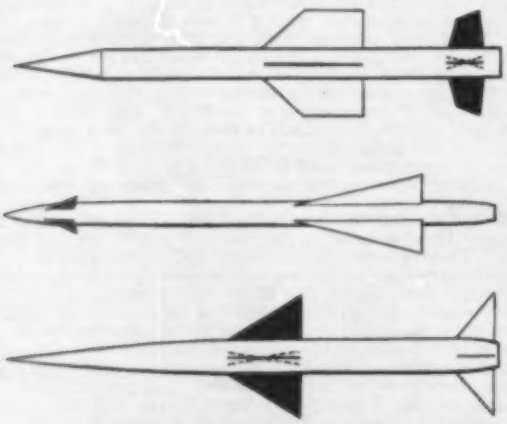

Fig. 2. Variation in control surfaces: moving tail (top), canard and moving wing. In these sketches the wing and control cruciforms are both in line.

Although *canard* layouts—in which the control surfaces precede the wings—are employed in some widely used American missiles, the most frequent British configuration is more conventional, with the wings placed ahead of the controls. One reason for the reluctance to specify a *canard* layout is probably that, when manœuvring, the main wings are operating in the downwash of the controls and the values of the lift reactions become difficult to predict; erratic and even reversed-sense motion can occur. Similar arguments also apply, in a less severe form, to the positioning of the controls behind the wings; and in some designs —such as Fireflash—the cruciform has been indexed at 45 deg to the wing cruciform to remove the controls from the severest downwash region.

Control surfaces for guided weapons (other than those for the subsonic bombardment types, which follow conventional aircraft practice, and certain American designs, such as Falcon) are of the all-moving pattern, no fixed surfaces being associated with them. These all-moving surfaces provide, by suitable differential action, the forces for rolling, pitching and yawing, and can simultaneously generate the necessary forces for initiating any type of motion. Consequently, ailerons are not required and the wings are completely fixed surfaces.

A variation in control layout within the general cruciform missile configuration can be achieved by transferring the function of the moving control to the wing and arranging for the rear aerodynamic surfaces to be fixed. Lateral forces for manœuvring the missile and differential forces for rolling are then generated by pivoting the wing and altering its angle of incidence relative to the centre-line of the missile body; this geometry is seen in Sparrow and Terrier. The rear fixed surfaces then perform the function of stabilizers, limiting movement of the combined centre of pressure of the weapon. One of the arguments in favour of this layout is that the response of the missile is faster than when the manœuvre is initiated by rearward-positioned control surfaces.

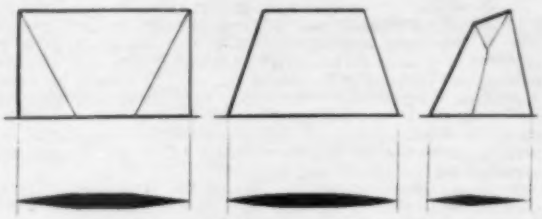

Fig. 3. Typical wings: rectangular parallel double wedge, trapezoidal biconvex and trapezoidal double-wedge.

Another point on which guided weapons differ aerodynamically from aircraft is the proportion of the total lift contributed by the body. In supersonic missiles most of this body lift is generated over the nose cone, which is usually of conical or ogive form; and, depending upon the relative proportions of body and wings, this component of the lift can contribute up to 15 per cent or more of the total. Presumably it would be possible, by making the body relatively short and fat, to generate from the nose cone alone the entire lift necessary to manœuvre the weapon; but control and stability problems would be considerable and test vehicles of this form have yet to appear.

Drag is always one of the biggest factors; and, in parallel with aircraft designed for supersonic flight, ultra-thin wings of low aspect-ratio are universally used. "Thin" is a relative term, but it is hard to avoid using superlatives when describing missile wings. High-speed aircraft are fitted with wing sections having thickness/chord ratios ranging from four to ten per cent. From examination of the wings of the missiles already shown to the public, it is clear that ratios ranging from five per cent down to as low as two per cent are in existence. The two-per-cent wings are usually solid, but for four-per-cent wings and above, fabrication might result in a lighter structure.

Wing sections are generally biconvex, double-wedge or parallel double wedge. All these profiles are symmetrical about the median plane, so that they are the same either way up. The lift-curve slope is the same for negative or positive angular displacements; and, as the missile body is also invariably symmetrical about its centre-line, there is no aerodynamic reason

for orientation relative to the horizon. Missiles are, therefore, often roll-stabilized but not position-stabilized. That is to say, automatic corrective action is taken by the control system to maintain the rolling velocity at or near zero, but the actual angular position of any wing pair relative to a datum is unimportant. (It should be noted that roll-stabilization is required only to prevent rolling motion induced as a result of mechanical misalignments or aerodynamic cross-coupling. Rolling as a manœuvre is never required, except where it is used to prevent deviation from the initial line-of-fire during the boosted phase of a ground-launched missile.)

Plan shapes of missile wings vary widely, although there appears to be some preference for forms with a moderately swept leading edge, a square tip and a straight trailing edge. Many missiles have pure delta or rectangular plan-forms. Aspect ratios are normally low, and this is a characteristic of all supersonic aerofoils: where, owing to the changed nature of the airflow, induced-drag reduction is no longer important. Moreover, low-aspect-ratio wings simplify handling, stowage and firing problems. For air-to-air missiles the wing span determines how far away the weapon has to be suspended beneath the wing of the parent aircraft, and consequently decides the size of the fixed launching structure that has to be carried.

Problems of stowage are most acute in the case of missiles designed to be operated by naval forces. If large numbers are to be carried in a ship's magazine, it helps greatly if the wings and control surfaces can be detached—though this hardly applies to defensive missiles, whose potential rate of fire would be much too high to allow time for the assembly and precise alignment of eight surfaces on each round. Precise assembly is mandatory, because the disturbing airloads developed by even very small angular misalignment of any aerodynamic surface could be sufficient to absorb so much effort on the part of the servo control system that the margin of power left for manœuvring would be severely restricted. (As missiles cannot be test-flown prior to service it is impossible to trim out an incorrect flight attitude induced by airframe misalignments. This trouble can be avoided only by imposing stringent manufacturing limits on all structural components. Such requirements will raise problems in the production shops even more severe than those already experienced with the integral-structure items for high-speed aircraft.)

The carriage of bombardment missiles aboard submarines has been suggested. Here, although space restrictions will be even more severe, it should be possible to carry out accurate assembly operations, as rate of fire will be low and the initiative in this case rests with the missile operator.

To some degree, the plan-form of missile wings must also be dictated by aeroelastic considerations. Wings having a thickness/chord ratio of four per cent and less must be susceptible to failure by flutter, owing to the low torsional and bending stiffnesses implied; although the wing-root attachment to the body can be made more continuous and torsionally rigid than would be the case with an aircraft. The wings are usually attached to the body by a multiplicity of connections, often socket-headed screws, distributed along the chord above and below the wing root. This indicates that the centre-section structure is not continued through the body to interconnect each wing-pair, but that the central structure consists of a thick-walled tube extending the length of the wing chord and internally free from obstructions. The constraint of the root in bending is thus likely to be considerably lower than it would be for a continuous centre-section.

Another aeroelastic defect to which thin wings are subject is divergence. The leading-edge section of a supersonic aerofoil is extremely thin and it is aerodynamically desirable to have as sharp an edge as possible. This is achieved so well in most missiles—and also in certain United States fighter and research aircraft—that the leading edges have to be protected by covers to prevent them from injuring personnel on the ground. This type of leading-edge structure consequently has little stiffness in the bending mode. If the stiffness is below a certain critical value, the incremental increases in air-loading experienced by the leading edge as it deflects will cause displacement to increase progressively until structural failure occurs. As the root sections of most missile wings are constrained along the entire chord, the leading edge tends to fracture along a line displaced at a small angle to the transverse axis. Thus, the fact that many missile wings have swept leading edges may be dictated as much from aeroelastic considerations as from aerodynamic ones.

One especially intriguing paradox is the difference in plan-forms existing between the wings and control surfaces. The wings generally have swept-back leading edges, square tips and straight trailing edges, whilst the controls frequently have a converse geometry of straight, or near-straight, leading edges, raked tips and swept-forward trailing edges. The controls are generally pivoted on an arm fitted at about 40 per cent chord. The control plan-form is dictated largely by the need to restrict the movement of the centre of pressure as the surface is moved, in order to keep the control torque within the capacity of the servo-power available. Since the control loads are brought to a

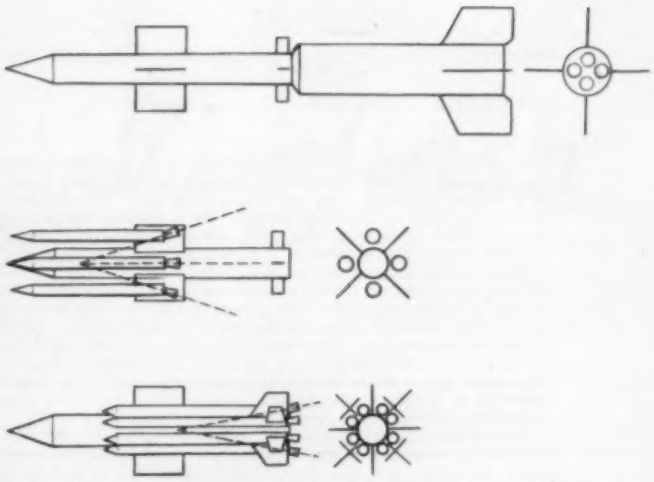

Fig. 4. Boost configuration: tandem (top); forward wrap-round, with canted venturis; and rear wrap-round, with boost fins.

shaft attachment, it follows from structural considerations that the thickness/chord ratio must be greater than that specified for the wings; in practice these ratios appear to lie in the region of six to eight per cent. Depending upon the plan-form, the cross-sections used for controls are of basic double-wedge or parallel double-wedge profile.

Defensive (anti-aircraft) guided weapons can be divided into two main classes, the air-launched and the ground-launched. The operational range and the active flight-time of an air-launched missile is considerably less than that of its ground-launched counterpart. (Air-to-air weapons are, in most instances, merely an interim solution to the air-defence problem.) A missile launched from an aircraft already possesses considerable kinetic energy. Its main motor or boost units accelerate it to a high supersonic speed. After burn-out, the missile coasts or glides under control for the remainder of its interception path. Its speed will eventually fall to a value at which the missile will be incapable of achieving its full design manœuvres; but if the interception course does not call for these manœuvres to be performed the missile will remain operational. Finally the speed will fall to a lower limit at which the manœuvre margin is so restricted that the missile becomes non-operational. It will then be necessary to trigger some self-destruction device.

Motors and Boost Units

Fireflash is unusual among air-to-air designs in that it is accelerated to its peak velocity by two external boost motors which separate at burn-out, leaving the engineless "dart" to continue in free flight towards the target. Other air-to-air missiles, such as the Falcon, are equipped with an inbuilt motor which is not jettisoned on burn-out. Missiles with external boosters have high drag during primary acceleration, but a small dart of lower drag is left to continue in free flight. The converse is the case for the missile with the internal motor. As designers of most air-to-air missiles favour the latter layout it may be assumed that it is the more efficient. Another factor which probably influences the choice in favour of the integral motor is that, if external boosters fail to deliver the same thrust for the same time, yawing will be induced; but design action can be taken to reduce this effect. Yawing cannot be serious with motors placed on the missile centre-line, even if the burning is erratic.

Motors and boost units fitted to air-to-air missiles are of the solid-charge type. Liquid-propellant motors are too complex to fit into such small structures and are also unnecessary in view of the brief firing time.

The power requirements of ground-launched missiles are more complex. In the first place, such a weapon has no initial kinetic energy, so that an additional launching phase (or boost phase) is required to accelerate the weapon from rest to above, or near, its operational speed. Acceleration is obtained by the traditional method of providing very high thrust for a brief period by employing external boost units, which fall away at burn-out. Operational speed is then maintained by an internal motor, which may be termed the "sustainer."

In the boosting of ground-launched weapons there is a remarkable divergence of philosophy between Britain and the United States. Most American SAMs (surface-to-air missiles) are fitted with a boost unit in tandem with the weapon, whilst the known British counterparts have wrap-round boosters. (Presumably this is the missile equivalent of the current aircraft-engine installation argument, "to pod or not to pod.")

With a tandem boost several motors are assembled into a single faired container which fits on to the rear of the weapon. The

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method of attachment can be designed to allow the sustainer motor to burn, with the boost motors, throughout the launching phase; or a triggering device can be arranged to light the sustainer towards the end of the boost period. At separation the missile flies on ahead of the boost assembly, which is retarded by aerodynamic drag. The separation is therefore likely to be clean and to cause the minimum disturbance to the missile. Another advantage of tandem boosts is that, should one of the boost motors fail to fire, or burn erratically, the out-of-balance yawing moment induced will be small, since the thrusts are grouped closely round the missile centre-line. Also, several boost motors firing together do not cease to burn at precisely the same instant; but as long as the overall thrust of the boost unit is greater than its drag it will continue to accelerate the missile. Only when the boost drag overcomes the aggregate boost thrust does separation begin.

Some disadvantages of this layout are fairly apparent. Perhaps the greatest objection is the considerable length of the weapon/boost assembly, and the concomitant difficulties of handling, together with the size of the launchers required. Existing ground-to-air missiles are approximately 20ft in length and boost unit lengths are of the order of 15ft, so that the overall length of the round at launching is in the region of 35ft. Servicing of the missile on the launcher then becomes difficult, and the rate at which the launcher can be trained in the direction of the target after reloading must be slower than for a more compact assembly.

Another disadvantage is structural. The tandem boost assembly is fitted with large stabilizing fins. If these fulfil their purpose in maintaining the assembly on a steady trajectory during the initial launching phase a large bending moment will be built up along the structure, reaching a maximum in the region of the boost-unit/weapon joint. The rear body of the missile must be designed to accept this, though in free flight the rear-body bending moments will be extremely small. Consequently, the skin thickness and weight of the rear body will be greater than it would need to be to meet free-flight manœuvring loads only.

In a typical British wrap-round boost arrangement, eight Demon rocket motors are arranged in four pairs alongside the missile body, each pair passing between the vee formed by the wings and control surfaces. The motors of each pair are connected at front and rear by spectacle-shaped castings. Dependent upon the particular geometry, the castings are themselves interconnected. Within these limits there are two main configurations. In one the nose-caps of the boost motors are roughly aligned with the missile's nose; in the other, the expansion nozzles of the motors are level with its base.

With a wrap-round boost assembly a mechanical system has to be devised to ensure that all four duplex units separate simultaneously. All eight motors are unlikely to cease burning at the same moment, but—provided they are mechanically linked—the unit remains in position on the missile as long as the aggregate thrust exceeds the boost drag. When, near the burn-out, it does so no longer, the complete boost assembly slides a short distance to the rear. This action then disconnects the front quadrants of the boost-motor pairs from each other. Films of wrap-round separations show that the boost units pivot outwards about some point in the region of the expansion nozzles, so that they open in a petal formation around the missile. When a predetermined angle is reached, their rear ends are released and they fall away freely.

That this outward-opening sequence is an essential part of the separation procedure is borne out by the fact that a small aerofoil, fixed at an acute angle to the line of flight, is often fitted between the boost nose-cones (e.g., Napier-N.G.T.E. ramjet). In an alternative version (seen on an A.W.A. test vehicle) the duplex boost motors are linked by common nose-cones angularly offset away from the missile body. The angle through which the axis of each cone or aerofoil is displaced must be substantially greater than the maximum yaw angle that the missile can attain just prior to separation, to ensure that a lift force is generated capable of pulling the nose of the boost unit away from the missile body.

A design difference which further distinguishes the forward wrap-round arrangement from the rearwardly situated variety is that the latter requires additional stabilizing fins as an integral part of each boost pair. During the boosting phase, the combined missile/boost assembly must possess a high degree of inherent stability to prevent it from diverging too far from the line-of-fire on to which the launcher is laid. As the controls are initially blanketed by the boosters they are unlikely to be operating at this stage—or that, if allowed to operate, they would be very effective. To achieve inherent stability it is obviously desirable that the overall centre of pressure of the boosted round should be well to the rear of the overall centre of gravity. As the boost motors probably weigh as much as the weapon itself, the c.g. is well up-front with forward-mounted boosts; with the other configuration, however, the c.g. is quite far back and auxiliary stabilizing fins are needed to displace the overall centre of pressure sufficiently far to the rear to maintain the desired static margin. Horizontal stub-wings are also often fitted adjacent to the boost stabilizing fins on the rear-positioned assemblies, presumably to ensure that the entire unit separates laterally.

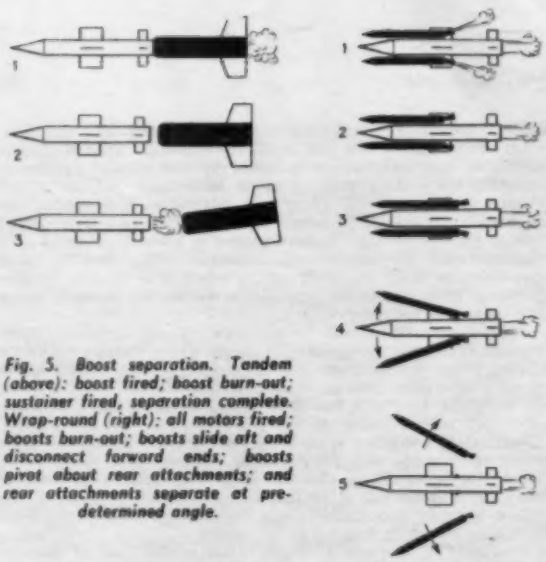


Fig. 5. Boost separation. Tandem (above): boost fired; boost burn-out; sustainer fired, separation complete. Wrap-round (right): all motors fired; boosts burn-out; boosts slide aft and disconnect forward ends; boosts pivot about rear attachments; and rear attachments separate at predetermined angle.

Another means by which it is possible to ensure that a missile keeps close to the line-of-fire during the boost phase is to spin it about its longitudinal axis. Any consistent tendency for the weapon to yaw in one direction then results in a flight path similar to a barrel roll centred on the line-of-fire. The rotation can be imposed by slightly canting the boost venturis, all in the same relative direction.

Where intermittent firing, or complete failure, of a boost motor occurs, the wrap-round boost assembly applies a far greater yawing moment than does a tandem layout. This effect can be largely overcome by canting the boost venturis outwards, so that the line of thrust of each motor passes through the overall centre of gravity, or as near to it as is practicable. This is well shown by the boost nozzles of Fireflash.

Airframe Structures

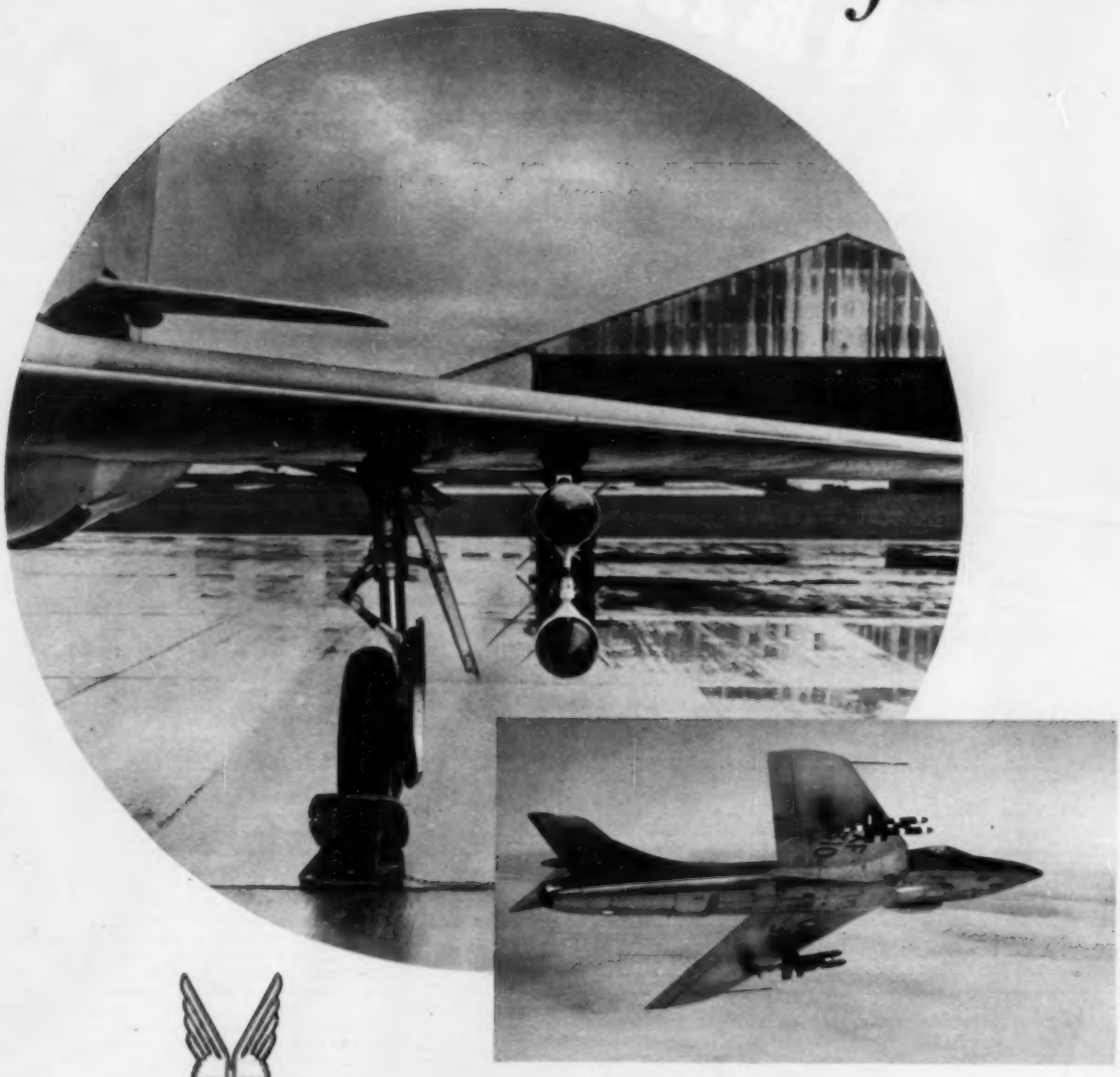
The structure of the missile body is likely to be fairly straightforward. Of the weapons so far revealed, the majority appear to be built up from plain cylindrical shells, each attached to its neighbour through multi-screw joint rings. As servicing and inspections must be carried out fairly frequently it is surprising to note the apparent absence of quick-release joints; a considerable design-problem is, of course, implied by a sufficiently rigid joint which, within the narrow confines allowed, must transmit torque and axial bending loads. If some genius could devise a metal-to-metal stress-carrying zip-fastener he would earn the gratitude of missile designers.

The principal troubles with the required thin-walled tubular structures are likely to be experienced by the production departments rather than the design office. From reasons of aerodynamic symmetry it is necessary that the body be truly cylindrical within very narrow limits. Light alloys tend to "drift" after machining (owing to the fact that the removal of metal unbalances the locked-in stress pattern), and the production difficulties presented by such parts are well known. In fact, the production of g.w. airframes in the quantities required for operational service is likely to impose a heavy responsibility on the workshops; and, no doubt, the full severity of the problem has yet to be felt.

For the highest structural efficiency, the body skin-thickness must increase from a nominal value at the nose and tail to a maximum in the region of the wings. Near the mid-portion the thickness of the body skin must be sufficient to carry the longitudinal body bending moments as well as the transverse bending moments fed in from each wing. The severity of these bending moments assumed for the design calculations is dependent upon the manœuvre considered in association with the safety factor.

In conventional aircraft design an ultimate factor of 1.5 of the working load is specified (with an additional superimposed 1.5 factor for castings). These factors have been evolved to ensure that the structure has a virtually indefinite life. In g.w. design the only requirement is that, after being subjected to the most severe manœuvre it is required to perform, the structure shall not have received a permanent set or any damage which would prevent the missile from continuing to function effectively. Even this requirement can be further relaxed if the statistical probability of the missile encountering this most severe condition can be assessed, together with the variation in structural strength to be expected from "within tolerance" production items, and if some

Fireflash



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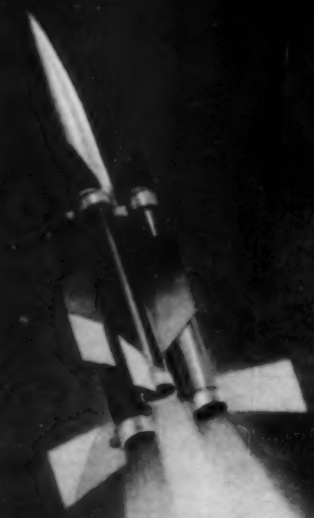

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MISSILE DESIGN . . .

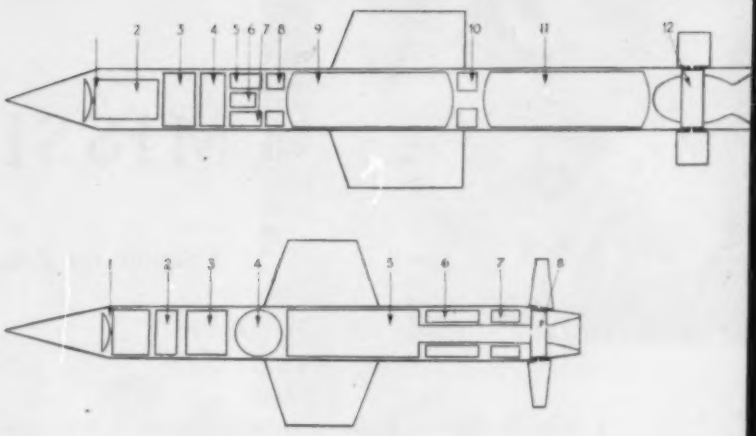


Fig. 6. Typical geometry of surface-to-air (upper sketch) and air-to-air missiles.

SURFACE TO AIR

1 Homing dish
2 Guidance
3 Warhead and fuse
4 Gyros and accelerometers
5 Alternator
6 Electro-hydraulic transducer
7 Hydraulic pump
8 Gas generator for accessory power
9 Oxidant
10 Turbopump
11 Fuel
12 Control ring

AIR-TO-AIR

1 Homing
2 Gyros and accelerometers
3 Warhead and fuse
4 Air bottle
5 Solid-fuel motor
6 Control electronics
7 Pneumatic control actuators
8 Control ring

level of structural efficiency below 100 per cent can be agreed. Under these conditions a performance increase can be achieved by virtue of the reduced weight, at the cost of in-flight structural failure in one or two exceptional cases. By the same token, it may be possible to dispense with the additional 1.5 factor imposed upon castings. It is, in fact, likely that missile structures will be worked to much higher stress levels than would be considered safe for aircraft.

There may be an exception to this contention. Both air- and ground-launched missiles initially take off from manned sites, and any design cases considered within the first few seconds of flight are likely to incorporate appropriately high safety factors to safeguard the launching crews against the possible consequences of failure. These factors are also likely to be specified for ground-handling.

The main operational phases of ground- and air-launched weapons are: ground handling; launching and boosted flight; boost separation; and controlled flight to target.

Stressing cases derived for the first three categories are always something of a guess, because—if everything works correctly—no great loads should be imposed. Some assumptions of failure or misalignment are necessary to provide working design figures, but, until considerable qualitative experience of handling and firing has been gained, the derived cases are likely to be very approximate. It is, however, unlikely that these design cases will provide the maximum loads to be experienced by much of the structure.

Loading cases derived for controlled flight are the most important and have the greatest influence on the design. Since they are determined by the specified performance requirements, they are likely to be fairly accurate assessments of conditions that will actually occur. The main flight cases that suggest themselves under this heading are: turn initiation; maximum-rate trimmed turn; and overshoot turn. Also associated with these cases would be the values of axial acceleration and rolling velocity assumed as a result of mechanical misalignments. All these would be considered at the highest and lowest operational speeds specified for the weapon and for fully fuelled and empty conditions.

Turn initiation is conceived as a condition of flight at zero incidence, when the full design acceleration is demanded in a particular direction. Maximum-rate trimmed turn is the maximum manœuvre rate specified by the performance requirements, and an overshoot turn results from the fact that servo-control systems do not ensure a "dead-beat" manœuvre (unless their sensitivity is reduced, in which case speed of response would be unsatisfactory).

For air-to-air weapons a series of design cases would also arise where the missile could be considered as an airborne store, subjected to the conditions encountered by its parent aircraft.

Whilst strength considerations are of importance in determining the design of a missile airframe it is likely that the exact form of the structure will be equally dictated by considerations of the required stiffness. Stiffness is important for aeroelastic reasons, and also from considerations of guidance and the correct functioning of the warhead fusing and other electronic devices.

Most missile bodies have a length/diameter ratio of the order of 14. This seems to give the best design properties, bearing in mind the conflicting requirements of total enclosed volume, disposition of controls in relation to the wing, structural flexibility, airframe weight, and size of individual pieces of equipment that have to be carried. (A notable exception is Sidewinder, for which the equivalent ratio is 22. It can only be concluded that this particular design specification calls for a much lower value of peak lateral acceleration—probably less than 10g—or allows an exceptionally thick body skin and a relatively high structure weight. Furthermore, the volumetric capacity of the body must be below average.)

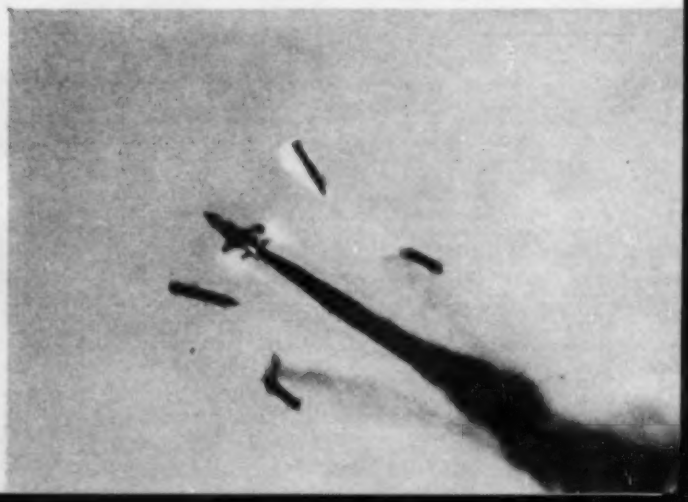
Another important aspect of design is the choice of constructional materials. Operational speeds of existing missiles range from subsonic to around Mach 3. Missiles at the lower end of this range are the "aircraft-type" bombardment weapons, whilst those at the other end are the defensive anti-aircraft weapons. The maximum operational life of an air-to-air missile is likely to be of the order of 20 sec from launching to interception of the target (or self-destruction); for its ground-launched counterpart the period probably ranges from 1 to 1.5 min. Although the speed is high, kinetic heating of the structure is usually unimportant, as no considerable rise in body temperature can occur during the brief flight-time. The main airframe materials are therefore the light alloys, both magnesium and aluminium.

As the storage life of a missile must be good, magnesium and its alloys must be well protected to minimize the possibility of corrosion. Magnesium is likely to be specified where stress levels are low and where a limit is placed on the minimum skin thickness to prevent failure of the structure through local instability. Such alloys may also be specified for non-load-carrying components where stiffness is desirable, such as chassis and supporting brackets for equipment. Again, the absence of a human crew makes the use of approved aircraft-specification materials unnecessary. Commercial-grade alloys are suitable, provided the same structural efficiency can be attained; and, if stiffness is the prime consideration, this condition should easily be met. As guided missiles might have to be built in quantity under wartime manufacturing conditions, it would be desirable if all the commercial and aircraft-material specifications could be rationalized into several broad strength ranges so that the material for any given component could be selected from a number of alternatives.

Ideally, of course, it would be advantageous if major missile components could be pressed out in such a manner that no further finishing operations were required. This may be possible if a suitable reinforced-plastic structure can be developed. The two main structural plastics available are resin-bonded glass-fibre and resin-bonded asbestos-fibre. Unfortunately, although glass-fibre possesses high static strength, it has a low value of Young's Modulus ($E = 2 \times 10^6$ lb/sq in). Owing to the importance of structural stiffness, bonded glass-fibre materials are, therefore, unlikely to be extensively used. The plastic materials reinforced with asbestos have a better value of E. ($2.1\text{-}3.3 \times 10^6$ lb/sq in) and could be used for wings, where the loads are diffused through root connections distributed over a major portion of the chord. These materials may also be suitable for the more lightly stressed extremities of the body, i.e., the rear body and nose cone. Such a structure is found in Falcon.

In conclusion, it should be noted that this account has not referred to some of the more pressing problems, as one of the objects of security is to prevent interested parties from knowing which *are* the unsolved questions. That they do exist can be inferred by the tardiness with which guided weapons are coming into service, despite the confident predictions of a few years ago.

The missile shown on p. 885 sheds its boosters and continues on its sustainer. The fin-tip flares are to facilitate camera tracking.



MISSILE TESTING

Weapons on Trial: a Series of Controlled Experiments

IN the development of aircraft the first machines of each particular type (or, in earlier days, the prototype) are thoroughly tested over a period of months or years. A considerable proportion of the desired information is already known before the wheels of the first aircraft leave the runway, as a result of rig tests and ground programmes on more or less complete aircraft. When flight trials do begin, any amount of instrumentation can be carried and the records of every item which needs to be measured can be analysed relatively at leisure, and design modifications fed in with assurance.

Should something completely unforeseen occur, it is usually possible for the pilot to make corrections on his own initiative and also to obtain detailed first-hand observations of the malfunction. Should the aircraft have to be abandoned, the pilot's statement may in itself enable the design team to pin-point the source of the trouble; and it is also frequently possible to recover virtually all the records from the airborne instrumentation.

By contrast, guided weapons present serious difficulties. The mere fact that there is no pilot is a tremendous handicap, for it places the design team in absolute dependence upon the readings of the airborne test equipment and the results obtained from ground stations. In most cases a missile cannot be fired more than once, and inability to fit a satisfactory recovery system—coupled with the fact that missile ranges may lie over the sea—frequently make it impossible to retrieve anything.

Typical test vehicles, with their instrumentation, may cost tens of thousands of pounds and the number that can be fired is accordingly strictly limited. The basic planning of the firing programme is therefore a direct compromise between the limitations of the permitted expenditure and the statistical approach to the problem. A statistical approach is essential, because no two missiles can be made exactly alike. Wings, for example, will vary from round to round as a result of minute differences peculiar to individual machine-tool operators, jigs or manufacturers; and rivets or bolts may be tightened by different amounts, giving varying degrees of structural joint elasticity. Even if two rounds were theoretically identical, varying atmospheric conditions would affect the aerodynamic constants and the performance of the motor. The best that can be done is to use standard statistical methods to calculate the minimum number of firings from which sufficiently accurate final results can be obtained.

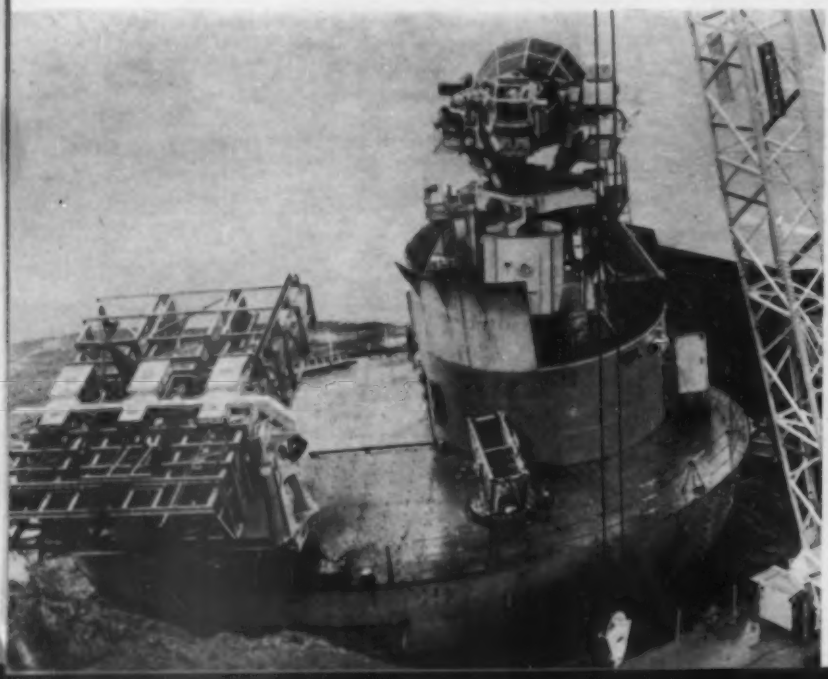
At the outset very little may be known of the conditions under which a particular missile series may have to operate, and the planning of a trials programme inevitably involves a number of calculated risks.

It should not be inferred that these are risks to life and limb; this is evident from the fact that nobody in the guided-weapon industry is paid danger money, and residents of the areas surrounding firing ranges require no special insurance and do not receive regular danger warnings. The element of chance is introduced by reason of the fact that the total number of firings from which the final results must be obtained do not permit the programme to be advanced in as many logical steps as might be considered desirable.

Components may frequently have to be used in flight before a significant number have been flown in survival trials and proved satisfactory. Ideally it is desirable to evaluate the performance of, for example, a gyroscope in a test vehicle which is not dependent on that gyroscope for control. After a number of such firings it would be possible to assess the performance of the new gyro and any shortcomings could be made good before the unit had to take its place in a complete missile system.

It is, of course, quite impossible to monitor behaviour of each element in the long chain of guidance and control in an actual missile. Recordings are therefore made of those quantities which are expected to be the most rewarding, and the performance of the remainder is estimated purely by inference. The instrumentation will vary from round to round. For recording the behaviour of the control and guidance equipment it is likely to involve either scratch recorders or the telemetering of data to receivers and recorders on the ground. The first method is satisfactory only when the recordings are likely to be recovered and is therefore basically restricted to use over land ranges, such as those at Woomera and Larkhill (Salisbury Plain). It is also limited to the recording of movements, such as the displacement of an accelerometer-weight or the angular position of a control surface.

Telemetering, however, is independent of the eventual fate of the missile and is also capable of converting into a suitable radio signal any type of input in the form of a d.c. voltage or a changing inductance. Transducers, of a variety of types, are employed to obtain such inputs from the various factors which have to be measured, such as liquid pressure, strain value, temperature and acceleration. Each telemetry sender can accept several inputs (usually 24 or more), which are sampled at high speed and transmitted to the ground receiver, where they are placed on a permanent film record for future analysis.

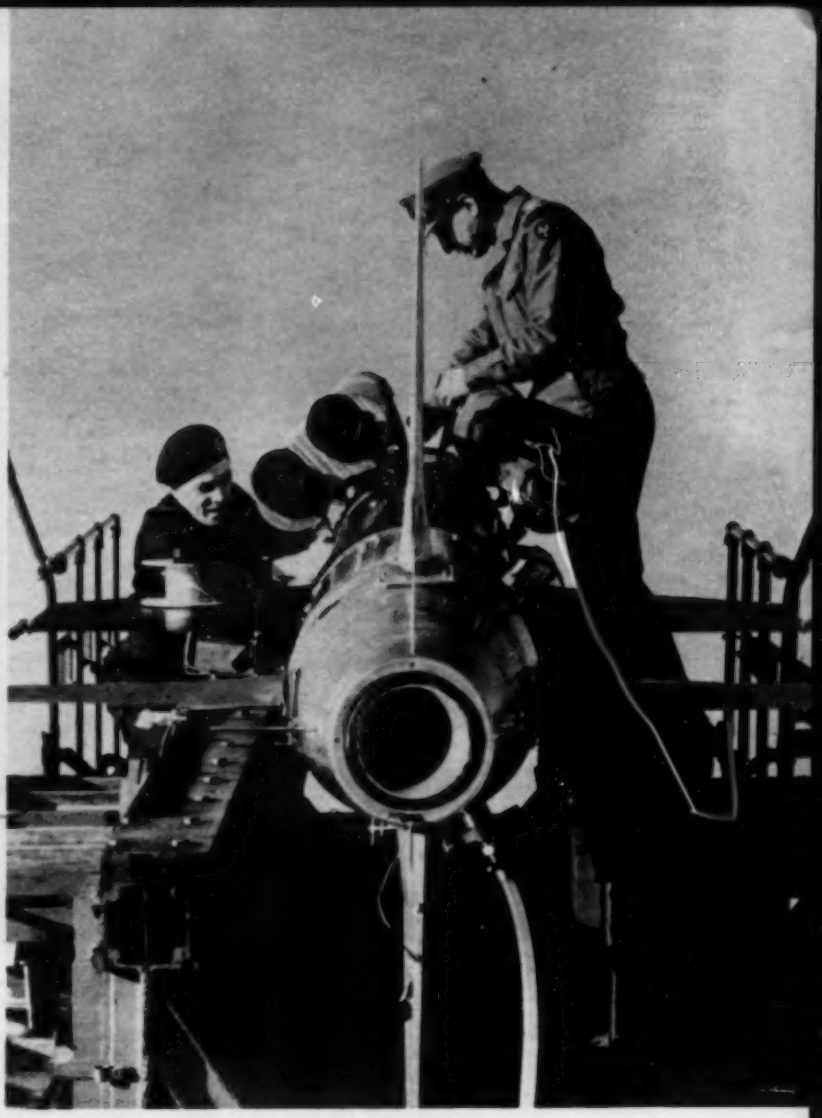


Telemetry was discussed at some length in our issue of October 23, 1953. The original transmitter in British missile work was the reliable S.R.D.E. sender Mk 2, or the Metrovick Type 232. A modern equipment is the E.M.I. or Murphy-made Type 620, far smaller and more efficient. Aerials may be suppressed into the body or wings or they may be small spikes projecting several inches from the body. A sampling switch is necessary to feed the transmitter with information from the various picking-up points, which may comprise 20 air-pressure tappings (dynamic and stagnation), a dozen mechanical strain gauges and several other transducers or pick-ups for temperature or control positions. It sometimes happens that several readings are required to be taken at precisely the same time, and this necessitates complete duplicated systems.

One of the most fundamental pre-requisites to the accurate evaluation of a missile flight is that the position of the missile should be known at any given time. This can be determined by any of, or a combination of, several methods.

In one arrangement the range is obtained by integrating Döppler frequencies. The Döppler principle is now generally well understood, and it depends on the fact that the frequency of a radio signal picked up by a moving body will be increased if the body is moving towards the

The three photographs on these two pages were taken at the M.o.S. establishment at Aberporth, where intensive tests of guided missiles are conducted. Civilians and personnel of all three Services work in close co-operation. On the right, a wing commander and a major prepare an RTV-2 for firing. Opposite, in the lower view, is the Navy's Clausen Rolling Platform, which can subject its triple launcher and radar equipment to the motions of a ship. The heading picture shows a range officer at the firing-control panel in the operations room.



transmitter and reduced if it moves away, just as the apparent pitch of a locomotive whistle varies according to whether it is going towards, or away from, an observer. At short ranges it is possible to obtain quite satisfactory reflections from a bare missile airframe (the "skin Döppler" technique), but at greater distances the missile has to carry a transponder. The latter, a familiar device used on radar targets, amplifies the reflected signal and also doubles its frequency. This is compared with the original and the resulting beat frequency gives the velocity. The larger and positive return signal from the transponder is particularly valuable at the end of the boost phase of a ground-launched weapon, when the sky may be full of falling metal from the boosters and attachments.

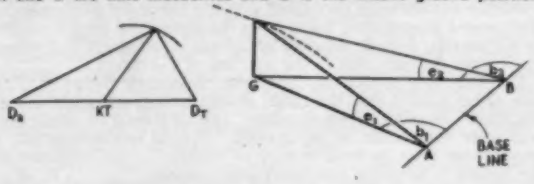
The diagram below clarifies the method by which integrated Döppler frequencies can give range while a single kine-theodolite gives direction. Both accurate and convenient, this principle is widely used. Alternatively one can employ two kine-theodolites, as also shown. Yet another method is to use the M.T.S. equipment, with two lock-on radar dishes, one behind the launcher and the other some way down the range, whose bearing and elevation are recorded. Such an arrangement is valuable in bad weather, when visual contact may quickly be lost. One of the most-used radars—in Britain and the U.S.A.—is the old American Type 584 set, used for anti-aircraft work in 1944-45. It has features which make it eminently suited to missile work, including quick servo response, good range and multiple drive outlets.

Perhaps the worst job in missile development is the reduction of data. A single flight lasting a minute or two may produce literally millions of figures, from film, photographs, punched card, magnetic wire or tape recordings, from telemetry and other sources. Pending the availability of fully automatic systems—which must come—readers are used which specialize in various systems. In Col. 2 is outlined one of the typical British systems currently in use to obtain missile-position data, and below it is a proposed replacement system. In America more advanced arrangements are already in use. The Potter Instrument company have evolved a unit which digitizes (if such a word is permissible) Döppler information direct on to magnetic tape for storage; and the H. A. Wagner company's Radott (Recording Angular Data Optical Tracking Theodolite) system instantly converts position information into punched-card or tape form. At the "Open Day" of the National Physical Laboratory this year a plotting-table unit was on view, capable of working automatically from punched-card data.

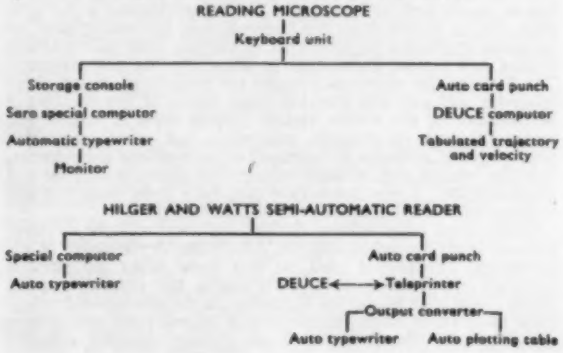
As a striking photograph overleaf emphasizes, cameras are mounted on the target aircraft. In most cases it carries a streamlined "pod" at each wing tip, and a typical load for one pod is a total of eight cameras. The latter are high-speed, shock-proof cine units with 145-deg wide-angle lenses so that the whole battery has a perfect view of the whole area of sky around the aircraft. The cameras are normally started and synchronized by radio pulses from the central timing unit of the range. Every single record associated with a firing is precisely related to range time—which is itself governed by a quartz-stabilized clock at the range head.

In the development of a sophisticated missile system the first firings are relatively simple and are aimed at the proving of the airframe, sustainer, boost configuration, stability, and equally basic problems. To save expense scale models may be employed for certain trials at this stage. It is only at this period of development that it is possible to carry out the survival trials already

Two systems of tracking, described in the text above: left, D_A and D_T are Doppler transmitter and receiver, and KT is a kine-theodolite; right, A and B are kine-theodolites and G is the missile ground position.



Typical data-reduction system in current British use and (lower diagram) a suggested method to replace it.



Taken from a Firefly U.8, this is believed to be the first photograph yet published showing a targets-eye view of a surface-to-air missile. Slight distortion is caused by the wide-angle (145-deg) lens. Clearly visible are the sun, the weapon's tracking flares, and the motor smoke-trail extending back to the distant Welsh coast. All photographs illustrating this article are Crown Copyright.

MISSILE TESTING . . .

mentioned, and also to investigate quantities not directly concerned with the main object of any particular firing. For example, it should be possible during the series of firings to check the performance of the sustainer motor, and also to measure the saturation temperature of the nose, the air pressure in and around the body and the vibration levels throughout the structure.

One might expect a typical development programme to pass through the following stages:—

(1) *Stability and boost-separation trials*—measuring in addition such items as nose temperature and base pressure.

(2) *Sustainer-motor trials*—also measuring internal temperatures and vibration levels throughout the structure.

(3) *Control trials:* It is likely that these will begin by feeding in a pre-determined programme to check that the complete system operates properly during various manœuvres and at limiting control-surface angles. Measurements would be taken of control-surface power, hinge moment and aerodynamic damping.

(4) *Guidance trials*, either with or without the control equipment. At the end of the development period the near-production rounds would be fired against radio-controlled target aircraft—such as the Firefly U.8 and the Jindivik—and a number of rounds would be fitted with explosive warheads.

At the end of such a programme the development of the basic missile might well be complete. Service evaluation is the next stage, for up to this point the eventual user has had to base his personnel and stores requirements on extracts from the reliability studies and similar documents produced by the manufacturer. The Services will therefore evaluate the weapon to confirm these estimates and will also examine every aspect of the operational performance of the system against various types of targets and under all kinds of climatic, geographic and other conditions, paying special attention to extremes of atmospheric temperature, moisture content and, in naval missiles, the effects of salty air and shipboard life. Large numbers of men have to be trained at this stage to carry out the various new specialist tasks.

Unlike most other industries, that concerned with the development of guided weapons requires concurrent development of the measuring instruments used, so that there arises the peculiar situation of instrumentation determining the condition under which it will have to operate. Examples are the continued development of vibration accelerometers and of the telemetry transmitters associated with them. At times the answers obtained, although later proved correct, are difficult to explain or even comprehend, and require a completely new approach to the design. Stress levels may become unexpectedly high as a result of the extreme vibration which may be experienced in certain rounds, and fatigue is quite likely to cause the failure of at least one link in the complex guidance and control chain. It is therefore essential to provide a statistically evaluated number of spare missiles to take the place of those which fail.

In parallel with the flight trials a number of static tests have to be carried out in order to prove the ability of all the equipment to withstand one or more aspects of its future environment. Various components and complete missiles are vibrated through whole ranges of frequencies to determine the points at which resonance occurs and to reveal any inherent weakness. Other tests include temperature cycling, humidity tests, experiments in altitude chambers and tests which impose high accelerations or impulses. The latter are necessary to ensure that the complete airborne system can withstand the shock of launching, and they are frequently carried out by dropping the items under investigation on to lead blocks in special rigs while the performance of the equipment is monitored. Sustained-g tests are executed with the aid of large centrifuges.

Not only do all such tests have to be made on the statistical number of specimens of every type of component after the completion of design, but they also have to be completed, and any necessary modifications effected, before the components are required for flight. It is also necessary to test "production" components throughout the programme to ensure that the original design and workmanship is being adhered to. At various points in the development, complete missiles will be "fired" without ever leaving the ground. The launching and flight sequence will be simulated in special test-beds to confirm the performance of the motor and also to check the operation of all other equipment, including the effect of flame and smoke on radar and guidance signals and telemetry transmissions.

The actual conduct of an individual trial depends on the object in view and on the methods of the establishment or company concerned. Nevertheless, one principle remains unaltered throughout: the firing is part of a controlled experiment and must be conducted with the minimum of unknown factors. Not only is every development round most carefully manufactured and inspected, but even the most trivial departure from standard must be recorded, in case it contributes towards some unpredicted performance. Casual onlookers might conclude from observing such trials that, in view of the tremendous number of factors which can (and usually do) delay its departure from the launcher, the missile concerned would be utterly useless as a weapon.

It is, however, inevitable that protracted pre-flight checks should be conducted both on the missile and on the great array of observers, radar, cameras and recording equipment throughout the entire range in advance of each firing, virtually none of which would be necessary in the firing drill of a Service weapon. Frequently a test firing has to wait for perfect weather conditions, because it is necessary for ground kine-theodolites to follow the missile for many miles down the range to enable the trajectory and other factors to be correlated with the estimated performance. High-speed photographs taken from the ground, or even from the target aircraft, provide valuable additional information and sometimes gives the only clue to the solution of a problem.

In operational service the conditions are entirely different. The sole object then is that the target should be hit; and high winds, fog, rain, "deviations from standard" (which should be negligible) and other factors can all be ignored. Should any missile fail, a good round must be fired at once to replace it. Investigation of the failure is a wholly secondary undertaking. R. A.

GUIDED MISSILES 1956

A "FLIGHT" COMPILATION

FACED with the task of producing a survey of the world's guided missiles, a writer is caught between security on the one hand and science fiction on the other. To be of any value a survey must be reliable, and we have used the utmost endeavours to ensure the accuracy of the surprising number of words which fill the subsequent pages of this issue. None of the information has been gleaned by cloak-and-dagger methods; and the fact that the American section fills over 60 per cent of the total reflects the transatlantic value of publicizing one's product. Altogether the survey is certainly the most complete yet attempted anywhere, and it portrays the products of an embryonic industry which is already one of the world's largest.

GREAT BRITAIN

WHAT has sometimes been described as "the first guided missile" was developed by the late A. M. Low for the Royal Flying Corps in 1915-1918 (as related in our issue of October 3, 1952). It was a rudimentary experiment, but by the early 1930s the techniques of radio control were sufficiently advanced for 550 de Havilland Queen Bee target aircraft to be standard Service equipment. As early as 1927-9 the radio-controlled Larynx (powered by a Lynx and fitted with a warhead) had been successfully tried out by the R.A.F. in Iraq.

In 1945 Germany was the dominant missile nation; later knowledge has shown how fortunate it was that she was beaten before her missiles could play a really major part. Nobody can deny that German work taught us much; but their defensive missiles were all aimed at employment in a "piston-engined" war. Britain decided to take a remarkable gamble, and one which applied to all weapons of war. No new conflict, it was argued, would break out before 1957 or thereabouts. In the intervening dozen years all effort would be applied to the development of advanced weapons. Thus it would be possible to avoid expenditure needed by interim equipment that would quickly become obsolete.

It is this gamble which explains the absence of a British counterpart to the Sabre or B-47; and it explains why we have no Nike or Terrier or Sparrow or Falcon. It also partly explains why so little of our guided-weapon work has been made public. No useful purpose would be served by publicizing developments which, although of immense long-term importance to our security, could bear little fruit for a period of years.

The heading illustration shows the Nike battery at Lorton, Virginia.

It cannot be over-emphasized that what we have attempted to do in the past dozen years amounts to a giant's stride into unknown regions. The dominating single factor has, of course, been the advent of nuclear devices of frightful destructive power. No longer is it sufficient to knock down enough enemy bombers to make raids "uneconomic." Today, one raid may be decisive; so *every* bomber must be destroyed before it even approaches our shores. Offensively, also, the guided weapon is revolutionizing warfare on land and sea.

In 1946 the Ministry of Aircraft Production merged with the Ministry of Supply; and the R.A.E., Farnborough, began to assume general direction of missile research, including firing trials at what was then G.W.T.W. (Aberporth, Cardigan) and rocket testing at the R.P.D., Westcott, Bucks. It was in this year that meetings were held to map our missile programme. Apart from some knowledge of supersonic aerodynamics, rocket motors and German experience, there was nothing on which to base the work. Fact-finding was a primary task. Many firms inside and outside the aircraft industry were brought in, and teams were sent to the R.A.E. to pick up a rudimentary knowledge of what was to be done.

By 1949 the foundations had been laid. It had been decided to let contracts for numerous test vehicles, each aimed at finding out certain facts, proving certain items of equipment, establishing correct procedures or making available necessary data. Starting with simple ballistic rounds and aerodynamic test vehicles, there later were the large and capable RTV-1 and -2, MTVs, CTVs, GPVs and RJTVs—and more besides. Such a scheme has undoubtedly paid off, and it has not only proved economical but has greatly accelerated the development of the real weapons. Primarily, the test vehicles have given the British guided-weapon industry a bed-rock of knowledge which is scarcely inferior in most essentials to that enjoyed by the far more

Guided Missiles 1956 . . .

(Great Britain—continued)

lavish missile industry in the U.S.A. It would, however, be ungenerous not to acknowledge the debt owed to American high-speed tunnels by our early missile programme.

It is fair to say that before 1950 no company in Britain could have embarked on the design of a really advanced guided-missile system with any hope of success. Since that year actual weapon programmes have been undertaken by many firms, and all are today in full sail, with as much hope of success as their counterparts in the aircraft industry. By far the greater proportion of our guided-weapon effort is dispersed among private firms—a most healthy sign and a good augury for the future. Even the basic research effort is now shared between government departments and industry.

Chief guided-weapon centre remains the R.A.E., with its outstations at Westcott and Aberporth (simple firings are also carried out at Larkhill). Also contributing are the Radar Research Establishment, Malvern; National Gas Turbine Establishment, Pyestock; Signals Research and Development Establishment, Christchurch; Armament R.D.E., Fort Halstead; Admiralty S.R.D.E., Portsdown; Explosives R.D.E. Waltham Abbey; and, of course, the great Weapons Research Establishment and long-range weapons ranges at Salisbury and at Woomera. Few details of Woomera have been made public since it was first described in our issue of April 13, 1951. It is nevertheless clear that the facilities available in Australia are vital. Since the autumn of 1953 the cost of experiments at Woomera and in Salisbury has been shared between Britain and Australia, and co-operation has since been excellent.

Early in 1953 the then Minister of Supply announced "Initially our efforts were concentrated on the problem of defence against enemy air attack. For this purpose a series of missiles has been evolved—some to be launched from the ground, some from ships and some from fighter planes. While these anti-aircraft missiles will be the first guided rockets to be brought into service, they will be followed by other types for use in various artillery and bombardment roles." In April of that year it was announced by the then Minister of Defence "after full consideration the Government has decided that the manning and operation of ground-to-air guided weapons will become the responsibility of the Royal Air Force." This decision arose principally from the need for unified command of the air space to be occupied by missiles and defending fighters.

In May 1954 discussions were held between the Ministry of Supply and the U.S. Defense Department, and other agencies. The primary aim was announced as the prevention of duplication of effort in the missile field and the establishment of machinery for joint consultation and mutual sharing of problems. Nevertheless it was announced earlier this year that our efforts were "approximately three years behind those of America in the overall field"—a rather sweeping contention that could be challenged. In spite of a statement in January 1954 that the "killing potential" of R.A.F. fighters would be quadrupled by air-to-air missiles about to be introduced, it was revealed this year that such weapons would not become part of the armoury of the R.A.F. until "new types" had been developed. It was also stated that work had begun on an ICBM (inter-continental ballistic missile); that an 8,000-acre site at Spadeadam Waste, in the Border country, had been considered as suitable for static firings of large (ICBM) motors; and that a Service-training missile range would be established at South Uist, Hebrides.

The following are extracts from the *Statement on Defence, 1956*:—

"The cost of new weapons is increasing, and will go on increasing.

"Good progress is being made with the [Naval] guided missile programme and it is intended that these weapons shall be installed in both the new cruisers and the new destroyers.

"We [the Army] shall be receiving in 1956 initial supplies of the American . . . . Corporal. Training in handling and development will start this year.

"For some time to come the manned fighter must continue to provide the backbone of our Air Defence system. The fire power and lethality of fighter aircraft will be markedly increased by equipping them with air-to-air guided missiles. The first generation of missiles will become available from production in the course of 1956-7. They will be brought into service with a special mark of Swift, and will be used to gain experience of this type of weapon.

"Although manned fighter aircraft and their weapons will improve, the surface-to-air guided weapon may well in time play a predominant part in Air Defence. A production order has been placed for these weapons for trials with the Air Defence system. Our aim is a guided weapons system which can break up enemy attacks before they penetrate over the coastline, and which can be integrated with our fighter defences.

"Particular emphasis is being placed on the ballistic rocket as a deterrent to aggression.

"Progress continues to be made in the development of guided missiles for each of the Services. . . . Some encouraging successes have been achieved in trial firings of both air-to-air and surface-to-air weapons. Service personnel are participating in trials on an increasing scale.

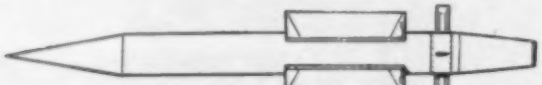
"The guided weapons trial ship [H.M.S. *Girdleness*] should begin work in 1956, and the plans for the first operational ship to use guided weapons as its main armament are going well.

"Close co-operation with the U.S.A. has continued with mutual benefit, particularly on guided weapons . . . the U.K. has offered to assist her allies in the development of guided missiles."

AIR-TO-AIR

de Havilland. Since 1951 the de Havilland Propeller Co. have been a major contractor to the Ministry of Supply in the development of guided weapons. The work is centred at Lostock, Farnworth and Lakefield in the North and Hatfield and Stevenage in the South. No details of the company's work may yet be made public. It is, however, of interest to list certain of the reports which have appeared in foreign journals.

In December 1954 it was stated in the U.S.A. that "Future British intercepters will be armed with the de Havilland air-to-air missile



de Havilland. This test vehicle was exhibited in the autumn of 1954. It may be presumed to be geometrically similar to the air-to-air missile which the company are reported to be developing. Length, about 7ft; span, about 1ft 6ins.

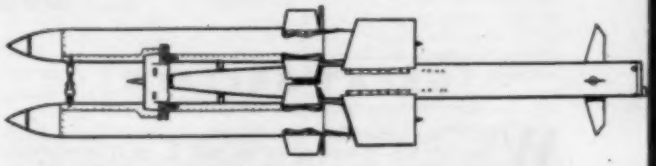
using an infra-red target-seeking device. Delta-wing Gloster Javelin may be the first R.A.F. intercepter to carry the de Havilland missile."

Early in 1955 a British writer reiterated that "de Havillands are working on air-to-air missiles suitable for mounting on such aircraft as the Javelin."

Last summer it was reported that the weapon would have a "liquid rocket" and would be "projected standard equipment for the R.A.F. with infra-red homing head." Another report states that the weapon "has high performance and good range characteristics, plus a highly sensitive infra-red heat-seeking system."

Fireflash. The Fairey Aviation Co., whose Weapon Division is based at Heston, Middlesex, were one of the first British companies to enter the missile field. For four years a strong team has been based at Salisbury, S. Australia, where, with Fairey Australia, a great deal of effort was expended in the development of early test vehicles.

Fireflash—originally it was known by a code name—is the first British guided weapon to have been publicly revealed. Although not then identified, it was pictured in a photograph of a firing from a Meteor night fighter which we published as early as August 28, 1953.



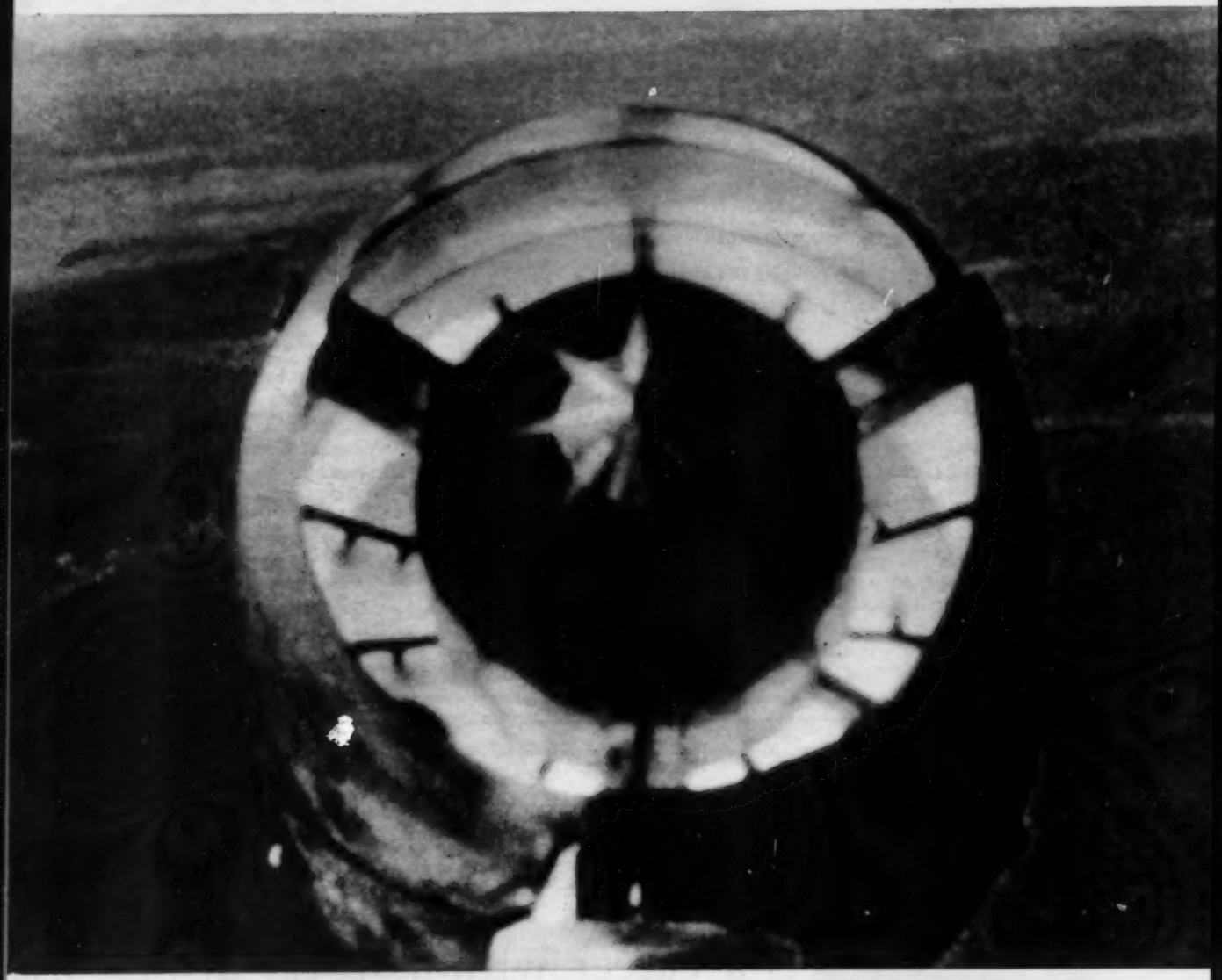
Fireflash. AAM with paired boost motors; no sustainer motor. Basic missile length, 7ft 6in; overall length with boost motors, 9ft 7in; wing span, 2ft 4in.

Plessey and Ekco were two of the chief collaborators in the development of this weapon.

The missile itself is an unpowered "dart," boosted to high supersonic speed by paired motors mounted above and below. At the burn-out point an explosive bolt shears the link joining the motors at the front end and each flicks away to leave a very clean missile capable of coasting for several miles. The missile is a beam rider, with aerials at the rear; there is, of course, no rocket-flame ionization to produce inaccuracies. Steering is effected with small cruciform controls mounted behind, and indexed at 45 deg to, the wings. The booster cases are wrapped and riveted, and the motor nozzles are canted outwards so that the thrust-lines pass through the overall c.g.

At the end of 1953 a development round, with an explosive warhead and proximity fuse, destroyed a Firefly drone. The latter was the first target shot down by a British air-to-air guided weapon. Both the Swift F.7 and a variant of the Hunter have been publicly shown with a Fireflash mounted under each wing (the Swift can, in fact, mount two under each wing). The Fireflash/Hunter combination is available for export. The missile itself, together with its trolley and "yes-no" ground-test gear, is in service-test production for the R.A.F. as a training and indoctrination weapon.

Vickers-Armstrongs. Nothing has been officially released regarding Vickers' guided-weapon programme. The following, however, was published by a British newspaper last month. "Another guided missile has been scrapped by the Government . . . it was being developed for the R.A.F. to replace guns in fighters. The new rocket, scheduled for



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BRISTOL

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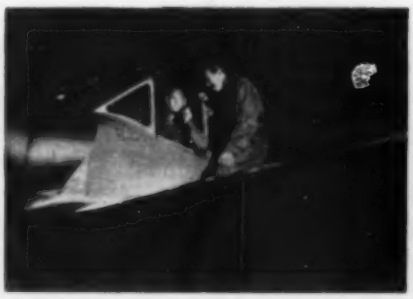
SPHERE OF ACTIVITIES. The world is your parish in the Royal Air Force. You may go to any or all of a score of countries—you travel fast and you travel far.



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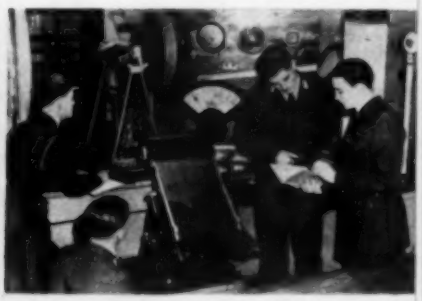

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SQUADRON AIRBORNE. Up to 40,000 feet, as you work up on your first operational tour. The Hunter is a master aircraft, responds superbly to a master.

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A hundred yards, or so, of reasonably level ground is all that the Twin Pioneer needs.

It can land at bicycle speed in 100 yards; can take off in 85.

With its unlimited utility and 'put-down-any-place' performance, the Twin Pioneer can carry the countless benefits of air transport, simply and cheaply, to anywhere in the world.

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Guided Missiles 1956 . . .

(*Great Britain—continued*)

production soon, has been abandoned because: defence chiefs decided it was too complicated and ambitious; it would have cost too much to produce in view of the economy drive; the money and man-power was needed for . . . the long-range rocket with the H-bomb warhead. The weapon was being developed for the Supply Ministry by Vickers-Armstrongs. An alternative and much simpler air-to-air weapon is being produced. . . ."

In fact, the position is not quite as described. The Vickers AAM was cancelled not because it was "ambitious" but because the aircraft which would have carried it was also cancelled.

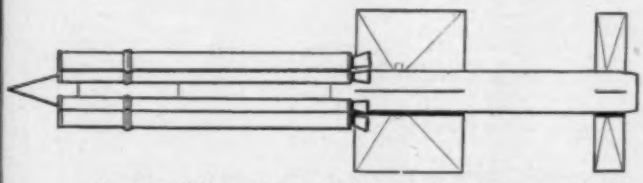
SURFACE-TO-AIR

Armstrong Whitworth. As the chief missile firm of the Hawker Siddeley Group, Armstrong Whitworth should be powerful and experienced. They were one of the first firms to establish both a design team and a research and development plant in South Australia and it was recently announced that approximately £1m would be invested in an extension to the facility at Whitley, Coventry, to make it "one of the largest concentrations of aircraft and missile research and design facilities in Britain."

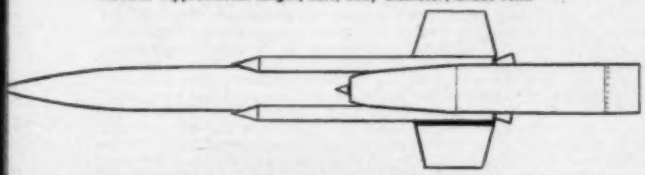
Officially, all that can be said is that A.W. are responsible for a naval anti-aircraft weapon, but more has been reported unofficially. In a Continental journal early last year, for example, it was announced that "Sperry Gyroscope Co. produces the guidance system for an Armstrong Whitworth ship-to-air missile powered by an Armstrong Siddeley motor. . . . Armstrong Whitworth are building a ship-to-air missile with four sets of wrap-round booster motors. Following extensive trials at Woomera, the type will go into production soon. The Admiralty reveals that it will test such a weapon on the guided-weapon ship *Girdleness* next year."

In the same year a British newspaper claimed that "a second British missile . . . nearing production is the A.W./Sperry Gyroscope Co. naval anti-aircraft rocket. This rocket was tested both at Woomera and, on a small scale, at sea off Aberporth in 1954. This rocket is one of several which will be used on the special guided-missile ships described in the Naval Estimates." The range was given as "20 miles or so."

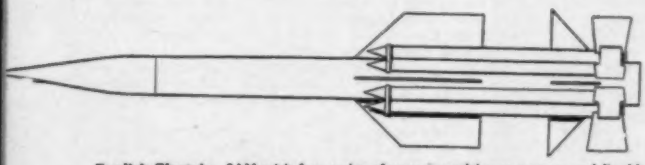
Finally, only last October, a British financial journal referred to "the Sir W. G. Armstrong Whitworth-General Electric team, whose shipborne guided missile is now being tested on H.M.S. *Girdleness*." In the same month an A.W. test vehicle, seeming to fit the above descriptions, was publicly fired from the Clausen Rolling Platform—a naval research facility—at Aberporth. The firing was reported in our issue of November 2.



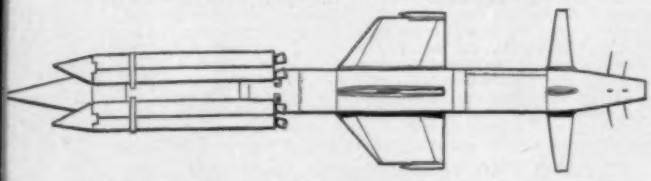
Armstrong Whitworth. Test vehicle, presumably similar in essentials to the company's naval SAM. Internal sustainer plus four sets of triple wrap-round boost motors. Approximate length, 20ft; body diameter, about 16in.



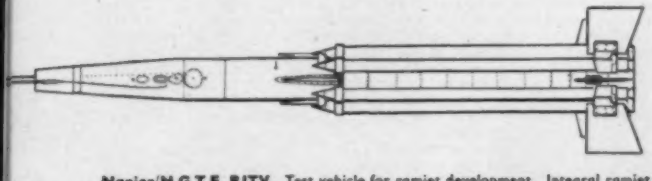
Bristol RJTV. Ramjet test vehicle, presumably similar in essentials to the company's SAM. Twin ramjets plus four sets of wrap-round boost motors. Overall length, probably well over 20ft. This drawing is provisional and approximate.



English Electric. SAM with four pairs of wrap-round boost motors and liquid-propellant sustainer. Overall length, about 20ft; wing span, about 4ft 6in.



GPV. General-purpose test-vehicle with four pairs of wrap-round boost motors and liquid-propellant sustainer. Typical dimensions: overall length, 25ft; span 5ft 1½in; body diameter, 17½in.



Napier/N.G.T.E. RJTV. Test vehicle for ramjet development. Integral ramjet plus four pairs of wrap-round boost motors. Overall length, about 20ft; no wings; body diameter, about 18in.

Bristol. It was in the summer of 1949 that the Bristol Aeroplane Company were allowed to state that both their Aircraft and Engine divisions were "to be engaged in the field of guided weapons." In February 1951 it was stated that "certain defence projects" would be accelerated by a technical agreement with the Boeing Airplane Co., and the following year photographs were released of a supersonic test vehicle for twin 6in ramjets.

Today Bristol Aircraft and Bristol Aero-Engines are heavily committed to the development of missiles and missile powerplants. In 1954 it was suggested in the U.S.A. that, in view of the tie-up with Boeing, a weapon like Bomarc (page 899) might result. Five months ago, indeed, a Continental report stated that the outcome would be a surface-to-air weapon capable of over Mach 1.5 and designed for use against supersonic aircraft.

This seems quite logical. Earlier this year the existence was made known of the Thor supersonic 16in ramjet, and it was then stated that an engine of this size could, at Mach 3 at sea level, develop a thrust equivalent to 90,000 thrust-h.p. It was stated that this unit was "mated with a pre-production missile"—which must clearly be of the SAM variety, a type of missile which Bristol are engaged in producing—and the accompanying sketch shows an approximation to a test vehicle fired publicly two months ago. The ramjet itself has been established as ready for service.

Early last year a British financial journal commented on the development of British ramjet anti-aircraft weapons "capable of 1,200 to 3,000 m.p.h. for 100 miles or more." At the S.B.A.C. Show this year Bristol shared a missile-development stand with Ferranti.

English Electric. It has frequently been pointed out that this industrial giant is unique, among British firms at least, in being capable of handling virtually a whole guided-weapon programme within its own resources. Apart from the massive experience of the parent firm in supersonics, advanced structures and general "systems" knowledge, there are the specialist abilities of the sister-firms of Napier (propulsion) and Marconi (guidance). Missile work is centred north of London, the main research centre being at Luton, Beds, and development resources being in the new production plant at Stevenage, Herts. There is, in addition, a strong and well-equipped trials team at Woomera.

For several years English Electric have been associated with surface-launched anti-aircraft missiles. Early last year a British report averred that "a number of guided missiles are nearing the production stage. One of these is the radar-controlled English Electric A.A. guided missile which can be fired from the ground to heights exceeding 50,000ft, and which can manœuvre and travel towards its target at speeds exceeding 2,000 m.p.h." Also in 1955 it was stated that the weapon would "have a main rocket and four sets of twin overlapping boosters."

Notes on missile models exhibited in September by the company were published on September 14. One of these models is depicted in the adjacent sketch. A development English Electric SAM is the subject of the photograph on page 885. A very similar weapon was fired publicly two months ago, as we related on November 2.

SURFACE-TO-SURFACE

Bombardment Missiles. Very little has been said officially of our work in this vital field, apart from the fact that "intensive ballistic-missile research is in progress" and that "particular emphasis is being placed on the ballistic rocket as a deterrent to aggression."

An announcement from Washington earlier this year referred to the "Air Force, Army/Navy and British programmes" for an intermediate-range weapon (IRBM) and announced that the large liquid-propellant rocket motor which Rolls-Royce, Ltd., are to make under licence from North American's Rocketdyne Division, would be used in the British missile.

In October a British newspaper stated that "work on Britain's first bombardment missile is now being given top priority, and the first, it is hoped, will be in production by 1960. The rocket motors for this will have a thrust exceeding 100,000 lb." The same report averred that "the English Electric Company . . . has teams working . . . on a ballistic missile."

TEST VEHICLES

Although not intended for production, the various test vehicles developed to support the British guided-weapons programme are closely akin to actual weapons. The following brief notes refer to the most common types.

RTV-1. Airframe by Marston Excelsior, propulsion by Armstrong Whitworth. Used for fundamental research into control and guidance systems. Fixed cruciform wings; rear cruciform controls of rectangular plan-form; tandem boost with multiple barrels in one casing; sustainer running on liquid oxygen and kerosine fed by pistons moved by gas pressure from a slow-burning charge. Overall length, 15ft 10in; body diameter, 10in.

Guided Missiles 1956 . . .

(Great Britain—continued)

RTV-2. Airframe and propulsion by Folland. Large vehicle for control and propulsion research (a cut-away drawing appeared in our issue of September 17, 1954). Fixed wings with 45-deg leading-edge sweep; trapezoidal rear control cruciform; eight wrap-round boost motors; bi-fuel sustainer. Length, about 15ft; body diameter, 14½in.

CTV (Gassiot vehicle). Upper-atmosphere research. Single-stage unguided vehicle; propulsion by Raven solid-propellant motor rated at 11,000 lb for 30 sec; weight, 2,600 lb approximately; trajectory peak, 25 to 120 miles.

GPV. Airframe and motor by Short and Harland. General-purpose vehicle for homing-heads, control configuration and liquid or solid sustainers. Configuration like RTV-2; eight wrap-round boosts and (usually) a liquid sustainer using H.T.P. and kerosine. Dimensions (these can vary): overall length, 25ft; span, 5ft 1½in; body diameter, 17½in.

RJTV. Supplementing the RJTVs of Bristol (see above, under surface-to-air), the Napier Flight-Development Establishment at Luton have for six years been developing ramjet vehicles under contract to the N.G.T.E. The first was fired in October 1950, and succeeding vehicles have been progressively more advanced. A full account was published by us on August 9 last.

UNITED STATES OF AMERICA

IT is generally accepted that the U.S.A. is the richest and, industrially, the most powerful nation in the world. It is, therefore, natural that she should have entered the guided-missile field along a broad front and on a tremendous scale, and her efforts have since been both prolific and diverse in character. Nevertheless, vast resources do not necessarily result in the best overall programme, and for the first seven years (to 1953) the American missile picture was clouded by its unwieldy size and lack of competent direction. Each branch of the armed Services was allowed a fairly free hand to work out its own salvation, and this produced duplication of effort and an appreciable amount of envy and internecine struggle for ascendency.

Requirements for all new weapons originate from the Joint Chiefs of Staff (the heads of the four Services). Joint proposals are formulated by the Munitions Board and the Office of Guided Missiles (and originally by the Guided Missiles committee of the Research and Development board, now defunct) who submit these to the Secretary of Defense (at present Mr. Charles E. Wilson). The latter then makes recommendations to the Service chiefs, who pass on the Defense Department view to their staff agencies. Most of the currently operational missile systems originated in 1945-6 and were frozen as designs in 1951 on the orders of K. T. Keller, then head of the Office of Guided Missiles. Among such systems are Nike, Corporal and Honest John (Army), Sparrow and Terrier (Navy) and Matador (Air Force).

Private industry, involving some thousands of contracting firms, was assisted in 1952 by the formation of the Guided Missiles Technical Committee of the Aircraft Industries Association. This committee was to "act for members on common problems and help military procurement specifications and requirements." At that time the whole missile industry was slowly stabilizing, and individual companies were able to plan ahead with some certainty. By 1953, partly as a result of the war in Korea, bulk contracts had been placed for a comprehensive range of weapons systems; yet the overall field was re-evaluated the following year to transfer emphasis to research and development. Assistant Secretary of the Air Force Roger Lewis then said, "it was found as a result of careful technical studies and evaluations that some projects for which production had been planned were not yet ready. . . ."

Such has been the success of individual programmes that a wide variety of missile systems are now operational with each Service. Nevertheless the overall picture is still imperfect, and the factor giving rise to the greatest worry is the most important single weapon of all: the intercontinental ballistic missile, or ICBM. In the past the Air Force has tended to dominate the new-weapon picture, and it was early given complete and absolute responsibility for all ICBMs. As is related on a later page, the programme for this "ultimate weapon" began in a half-hearted manner and without any clear schedule or end-product in view; moreover, when it was placed on something approaching a "crash" basis, it was soon realized that it was far too big for any normal contractor to handle. The whole affair was completely re-evaluated in 1953 (see Air Force, Col. 2).

Even more inauspicious was the start of the programme for the Intermediate-range missile (IRBM). Responsibility for operating such weapons has yet to be allocated by the Defense Department, who have merely hinted that the Service chosen may not be that which sponsored the research and development. The position has been made critical by the fact that there were initially two programmes for three Services: the Air Force missile has gone smoothly ahead and the joint Army/Navy programme has not. Anyone with foresight must have seen that the concept of a joint programme was impracticable, if only for the reason that the optimum Army missile could scarcely be fitted into any ship at all. At the time of writing (November 1956) no complete solution has been found, but the Army and Navy are at least going their separate ways, after a distressing controversy exceeding in bitterness even that generated by the Nike-Talos-Terrier dispute.

Since 1954 several realistic agencies and government committees have "investigated" the overall American picture, and it is likely that it will be a happier and more efficient picture as a result. Last January the Defense Secretary announced that he would appoint a "missile czar"—something that had been demanded for years. His title is Special Assistant for Guided Missiles to the Secretary for Defense, and he has executive ability; Eger V. Murphree was appointed to the post in March.

America has so far spent on guided missiles a total of more than £1,900m, or two-and-a-half times the cost of the original Manhattan Project, the atomic bomb. To give some recent figures, the 1955 requests from all Services amounted to £224m, making the total from 1951 reach £1,680m, divided up into £1,040m for procurement and production, £570m for research and development and £70m for facilities expansion and tooling. For the fiscal year 1956 the requests were £328m for production and £89m for research and development (£35.7m for the Air Force and £26.7m each for the Army and Navy). An indication of the build-up in production is provided by the expected 1957 request for £464m; for, although unit cost is now falling rapidly as thousands of rounds are made, bulk purchase of modern missile systems is by no means cheap.

Research and development cost first exceeded that for aircraft in 1951. On the production side the most valuable factor is the existence of a large number of truly capable industrial firms who have now been working in the field for years (in Britain we would say they had "got their feet wet"). They have brought 30 families of weapons to the "hardware" stage and form the nucleus of a billion-dollars-a-year industry.

U.S. AIR FORCE. The Air Force Guided Missiles Office was once a subordinate division of the office of the Deputy Chief of Staff, Operations, but in 1954 it was upgraded as a separate office directly responsible to the Chief of Staff. Procedures for study, evaluation and procurement of missiles have evolved from those laid down for aircraft, and appear to work well.

Missiles are divided into five categories: those launched from aircraft are designated GAR (guided aircraft rocket, or air-to-air missile) or GAM (guided aircraft missile, or air-to-surface); those launched from the ground comprise the IM (intercepter missile, or surface-to-air), TM (tactical missile, or short-range surface-to-surface) and SM (strategic missile, or global surface-to-surface). Operational formations for surface-launched missiles are organized along normal wing and squadron lines, with the prefix Tactical, Strategic or Air Defense; air-launched missiles are issued to existing aircraft units. As noted previously, the U.S.A.F. is the sole "owner" of the ICBM and it also has prime responsibility for missiles with ranges from 1,000 to 1,500 miles.

Of all weapon systems the ICBM is the largest and most important. In 1953 the Air Force—finally convinced of the practicability of the weapon—appreciated that the problems which its development posed could be solved only by bringing to bear on them an exceptional collection of engineering talent. After much deliberation a form of Air Force/civilian triumvirate was agreed upon—a unique establishment for a unique problem. The three partners are the Western Development Division of the U.S.A.F. Air Research and Development Command (which was created for the job), the Ballistic Missiles (formerly Special Aircraft Projects) Office of the Air Materiel Command and the guided missile division of the Ramo-Wooldridge Corporation. WDD is the overall system manager, BMO handles the paper-work and contracts and R-W provides technical assistance and engineering evaluation. Officers of the two Air Force agencies—experienced engineers and scientists—wear civilian dress and can act without authority from their Commands.

Of the several Air Force organizations interested in missiles by far the most important is the A.R.D.C., already mentioned. This very large, and technologically unmatched, Command has no parallel in any other Western air force, to the latter's great loss. The chief A.R.D.C. missile centres are Edwards (Air Force Flight Test Center), Wright-Patterson (Wright Air Development Center, and the guidance laboratory in particular), Tullahoma (Arnold Engineering Development Center, advanced propulsion, aerodynamics and gas dynamics research), Holloman Air Development Center, responsible for ground firing and static trials, operational research and sled tests), and, above all, Patrick (Air Force Missile Test Center).

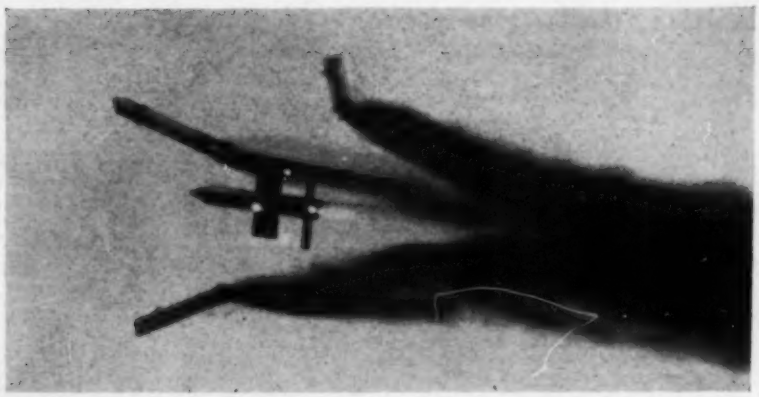
Patrick A.F.B. lies on Cape Canaveral in Florida. It faces south-east along what is certainly the largest missile range outside Russia and almost certainly the largest in the world. Operation of the establishment came under review in 1953, and it was decided to delegate much of the work to industry. In February 1954 Pan American World Airways were asked to operate the range, with the Radio Corporation of America as sub-contractor. At that time the range extended 1,200 miles south-east through the Bahamas, the Dominican Republic and Puerto Rico. During 1954 Santa Lucia was brought in, and by the end of the year 1,575 miles of telephone cable had been laid to join the down-range stations. Today 21 stations are operational in the first 1,600 miles, and since June action has been taken to stretch the range the full 5,000 miles needed for ICBM firings. Ascension Island is the terminus, and magnetic-tape instrumentation links and data-collecting ships are filling in the gaps.

U.S. NAVY. Most missile developments originate in the Bureau of Ordnance rather than in BuAer. Purchasing has, in fact, been along simple lines that reflect the Navy's regard for missiles as merely an improved type of ammunition. Installation of missile gear aboard naval vessels is, of course, handled by BuShips. A major, and well-considered, change in purchasing took place in 1953. Previously missiles had been bought for cost-plus-fixed-fee; since that year contracts have specified a fixed price, and incentives have led to appreciable reductions in cost and improvements in efficiency.

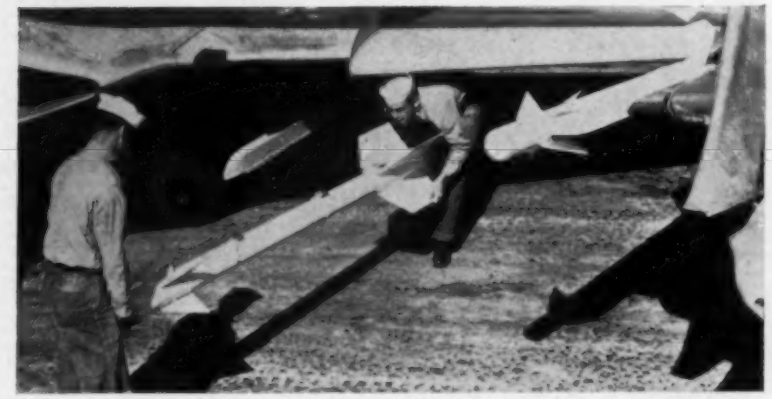
Small air-launched missiles (which are now painted grey, and not black as previously) present no special problems. Larger ship-borne weapons are proving difficult to accommodate even in craft specially designed to receive them. As an admiral succinctly put it recently, there is "a considerable lack of real estate" in any fighting ship, and the problems are intensified by the difficulty of providing centralized maintenance facilities and the need for stringent safety precautions at all times. A 30-foot missile like Terrier can, with difficulty, be mechanically constrained all the time it is on board, by employing mechanized magazines, transfer handlers and launchers. Nobody yet seems to have

Twin Terrier surface-to-air missiles on one of the automatic launchers of the large cruiser U.S.S. "Boston."

Air Chief Marshal Sir John Baker gives scale to a GAR-1 Falcon 1.

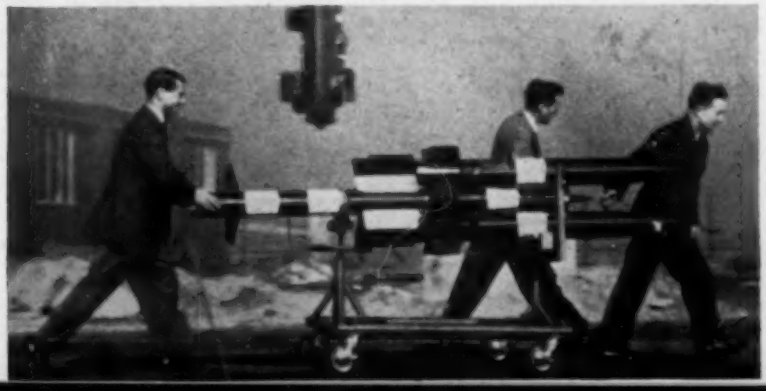


A Motor Test Vehicle (MTV), identical with an Armstrong Whitworth tunnel model, jettisons its twelve boost motors. The latter were originally clustered around the fore-body.



Ratings of the U.S. Navy slide a Sidewinder infra-red-homing missile under a wing of an F9F-8 at China Lake, the Naval Ordnance Test Station where the weapon was developed.

Sparrow 1 missiles are in widespread service with the U.S. Navy; those above are mounted on an F7U-3M. Below, Fairey engineers wheel out a black-and-white development Fireflash.



Guided Missiles 1956 . . .

(*United States of America—continued*)

worked out how to handle a ten-ton IRBM (with a hydrogen warhead) in a rough sea. Programmes for ship-conversion are listed in the descriptions of the missiles concerned. The eventual number of missile cruisers has been put at "dozens," of which those ordered after about 1959 will be built as such from the keel up.

The principle U.S. Navy missile establishment is the Missile Test Center, Point Mugu, Cal. Other important locations are the Naval Ordnance Testing Station, China Lake and Inyokern, Cal., and a missile range at Bonham A.F.B., Hawaii.

U.S. ARMY. Probably no other armed force can point to such a fearsome quartet as Honest John, Corporal, Nike and Jupiter A (or Redstone, as the last-named was originally known). All are products of Army Ordnance contracts and all are in service now.

Jupiter A is in several ways an exceptional weapon. Not the least of its peculiarities is that it was designed almost wholly by a team, employed by the Army, working at Redstone Arsenal. Such a practice is not to be perpetuated, and at present over 80 per cent of all Army missile research and development funds is going into industry. Even the development of less-complex weapons than missiles is now no longer the prerogative of arsenals.

Another, and even more far-reaching, change is currently taking place in Army thinking. Until 1955 the U.S. Army bought only what might be termed the "obvious" missiles; but, such is the revolution in military operations since that year, contracts are now in hand for troop-carrying missiles—and it would not surprise us to learn of a guided missile capable of making soup or digging a foxhole. Army missile procurement has more than doubled—to £289m—in the past year.

Greatest of the U.S. Army's missile problems is the perennial IRBM which—as the Jupiter family—is now being developed by Chrysler and the Redstone arsenal, independently of the Navy. Lacking the massive technical man-power of the U.S. Air Force, the Army have set up a Ballistic Missile Agency, on a "crash" basis. Head of the A.B.M.A.'s development operations is Dr. W. von Braun, principal designer of the German A-4 (V.2) and of the original Redstone weapon. Redstone Arsenal is still the major clearing-house of Army missile information, although most new design work is being farmed out to industry and universities. Chief test establishment is the Army Missile Test Center, White Sands Proving Ground, New Mexico, and other important establishments are the Army Ordnance Center at Aberdeen Proving Ground, Maryland, and the Army Center for Surface-to-air Missile Testing, Fort Bliss, Texas.

AIR-TO-AIR

BDM. These letters signify Bomber Defense Missile, and identify a system which has caused much controversy.

General Electric's Special Products Division holds a prime Air Force contract in respect of a bomber-defence missile. In this work they are being assisted by Hughes Aircraft, Bell Telephone Laboratories and the Raytheon Manufacturing Co. The guidance of this BDM should be adequate, since that is the speciality of each of the co-operating firms (a curious arrangement).

Raytheon now also hold a new Air Materiel Command contract for BDM work, and their Hawk SAM may be a basis for development. Two other major Air Force BDM contracts, both of which were re-evaluated last month, were held by Republic Aviation (with Westinghouse as subcontractor) and G.E. (with McDonnell as subcontractor). At the same time, the Arma Division of American Bosch hold an Air Force study contract for a BDM in competition with both.

Cherokee. This name refers to a new air-to-air weapon for the Air Force. Cook Research Laboratories are systems managers, and work began this year.

Diamondback. No details are available regarding this Navy study project for an air-to-air missile. It is known, however, that it succeeds Sidewinder, and may well be a heat-homer.

Ding Dong. Several years ago the Air Force discussed the practicability of an AAM with a nuclear warhead. It was argued that such a missile would be lethal even if it failed to pass in what was termed "close proximity" to its target. Disadvantages were that it would probably weigh at least 5,000 lb—partly on account of warhead size and partly owing to its obvious need for above-average range—and the fact that fall-out might prove hazardous to friendly territory.

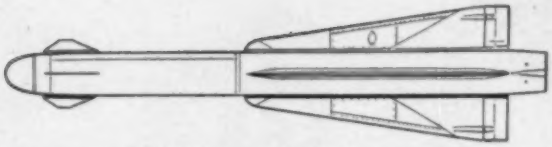
The latter factor was studied on April 6 last year, when a DB-36 launched a special nuclear weapon at a pattern of smoke trails laid at 30,000ft above Nevada. It was concluded that no dangerous radiation would reach ground level.

In February it was announced that a contract had been signed with Douglas Aircraft for a nuclear AAM with the above name. Guidance and fire-control is being developed by Hughes and propulsion will be by an N.A.A. Rocketdyne liquid-propellant motor. Air Defense Command are to gain experience with a device named Ting-a-Ling, ballistically identical but carrying only a spotting charge of explosive.

Duck This name is believed to identify one of the intercepter missiles forming part of the B-58 weapons system. Blue Goose (which may be an offshoot from Goose, described under SAMs) is a similar missile, likewise of Fairchild origin.

Falcon. The smallest homing missile yet developed, Falcon is nevertheless a lethal little weapon which can be fired in salvo from the latest U.S.A.F. intercepters. As far as is known (i.e., excluding Russia) it was the first AAM to enter service with any air force.

Its genesis was a General Electric guided-rocket study for the U.S. Air Force shortly after World War 2. Known as Project Dragonfly, this study was cancelled before much hardware had been made, but was reinstated in 1950 with Hughes Aircraft as prime contractor. At their main plant in Culver City, Cal, this firm have developed many remarkable examples of military electronic gear. Falcon is certainly one of



Falcon 1. AAM with 6,000 lb-thrust solid-propellant motor; no boost motor. Length, 6ft 6in; span, 2ft 6in (reduced to 1ft 6in in a later variant); body diameter 6in; weight, 112-122 lb; burn-out speed, M=2.8; operational range, 4 miles.

their greatest achievements, for its guidance package includes the world's smallest production homing receiver; yet the whole missile is designed to accept no less than 58 g during the launching phase.

By the autumn of 1952 Hughes knew that they had a workable weapon. The Air Force made available a large government plant in Tucson, Ariz, and Hughes moved in with a "producability" contract and tooled up. In November 1953 the complete missile (which was then designated F-98, as if it were a fighter aircraft) was tested in the gas dynamics tunnel at Tullahoma, and air-firing was also intensified. A few months later the U.S.A.F. discarded the idea of a second-source contract—they had furnished another electronics manufacturer with "sufficient Falcon data for educational purposes"—and in June 1954 the Tucson plant was enlarged to 1m sq ft, bringing the total government outlay on the facility to £5m.

The missile itself then began to engender a family of related, but improved, weapons. The basic designation became GAR-98 and finally GAR-1, and very large production orders were placed in 1954. The cost per missile, originally £31,600, came down to £9,000 in October 1955, when production was averaging 100 per month. Employment at Tucson had at this time reached 5,300 and the total GAR-1 backlog was standing at over £357m. When production reached 250 per month the cost was down to £6,800 and the ultimate price per missile at 350 per month—which should now be reached—is £3,600. Approximately half the cost is for subcontracted parts.

As the drawing shows, Falcon has a trim cylindrical fuselage. This is an assembly of precision-cast magnesium rings and skin, made by Solar at Des Moines, Iowa. Falcon is steered by a cruciform of rudders, similar to those of supersonic aircraft, used in conjunction with the nose fins; the delta wings provide lift and stability. Extensive use is made of glass-fibre-reinforced phenolic plastic, which can accept working temperatures of 500 deg F. The extreme nose is formed by a small radome, covering the forward-facing radar dish. Later Falcons are to have a rather more pointed radome than that shown. There is no booster, propulsion being provided by a single Thiokol solid-propellant motor giving 6,000 lb thrust during the 1½ seconds of burning time. In consequence, although the missile is quite "clean" the range is fairly short—but still much better than that of any aircraft gun.

During early trials Falcons showed exceptional accuracy—characteristic of homing weapons—and "hit drones repeatedly in vital parts so that, even with an inert warhead, QB-17s were often knocked down." With an explosive warhead, said Trevor Gardner, Asst. Sec. of the Air Force, "virtually every hit is a kill"—as p. 883 emphasizes.

At present the weapon is standard equipment for intercepter squadrons of Air Defense Command, although it may also be employed on day fighters. The most important carrier of the missile is the supersonic Convair F-102—and, no doubt, its derivative the F-106. The former carries six Falcons in an internal bay, the missiles being lowered on a tray and fired, in any chosen sequence, by the automatic Hughes fire-control system. By the spring of this year squadron tests had proved that the F-102A had "satisfactory systems capability." It was found that the Falcon could be fired up while the F-102 was still climbing towards its target. Another carrier of the Falcon is the Northrop F-89H Scorpion, which can take three inside each wing-tip pod and one on a pylon below each wing.

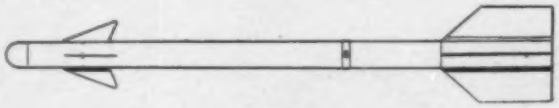
These aircraft became operational during the past few months, and squadrons are now training intensively, and very successfully, using Ryan Q-2 targets. Bulk deliveries are made by rail, with the missiles packed in Craig welded-aluminium boxes measuring 21in square by 88in. Hughes have spent £5.4m on test gear and flight-simulation equipment, and the Electronic Engineering Company produce a simulator which automatically checks out Air Defense Command rounds and notes any deviation from standard on a punched card.

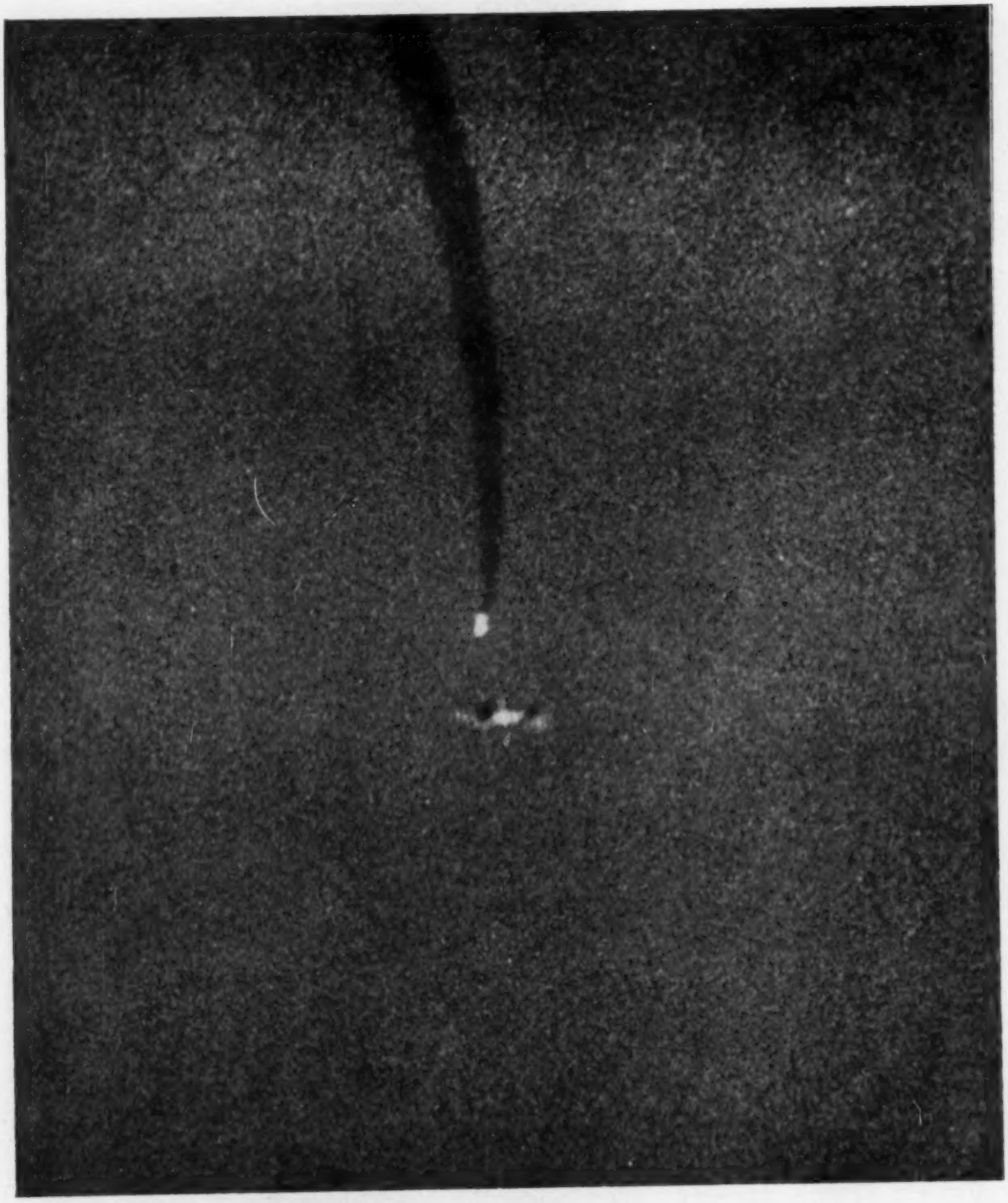
Early in 1955 it was announced that "much more advanced guided missiles than the Falcon are close to production." The whole family is developing rapidly to keep A.D.C. armed with the latest of the several derived versions; in particular, the guidance is being improved steadily to keep one step ahead of any possible countermeasures. Development is done at Culver City, but all production engineering and bulk manufacture is concentrated at Tucson.

Sidewinder. In many ways this slim air-to-air missile is unique. It is a heat-homer, it is of incredibly small diameter and its development must have broken all records for rapidity.

Sidewinder started as XAAM-N-7 at the Naval Ordnance Test Station (NOTS) at China Lake, Cal. This sprawling 1,000-square-mile establishment in the Mojave Desert employed a strong team, led by

Sidewinder. AAM with solid-propellant motor; no boost motor. Length, 9ft 2in; span, about 1ft 7in; body diameter, about 5in; weight, about 150 lb; burn-out speed, over M=2.





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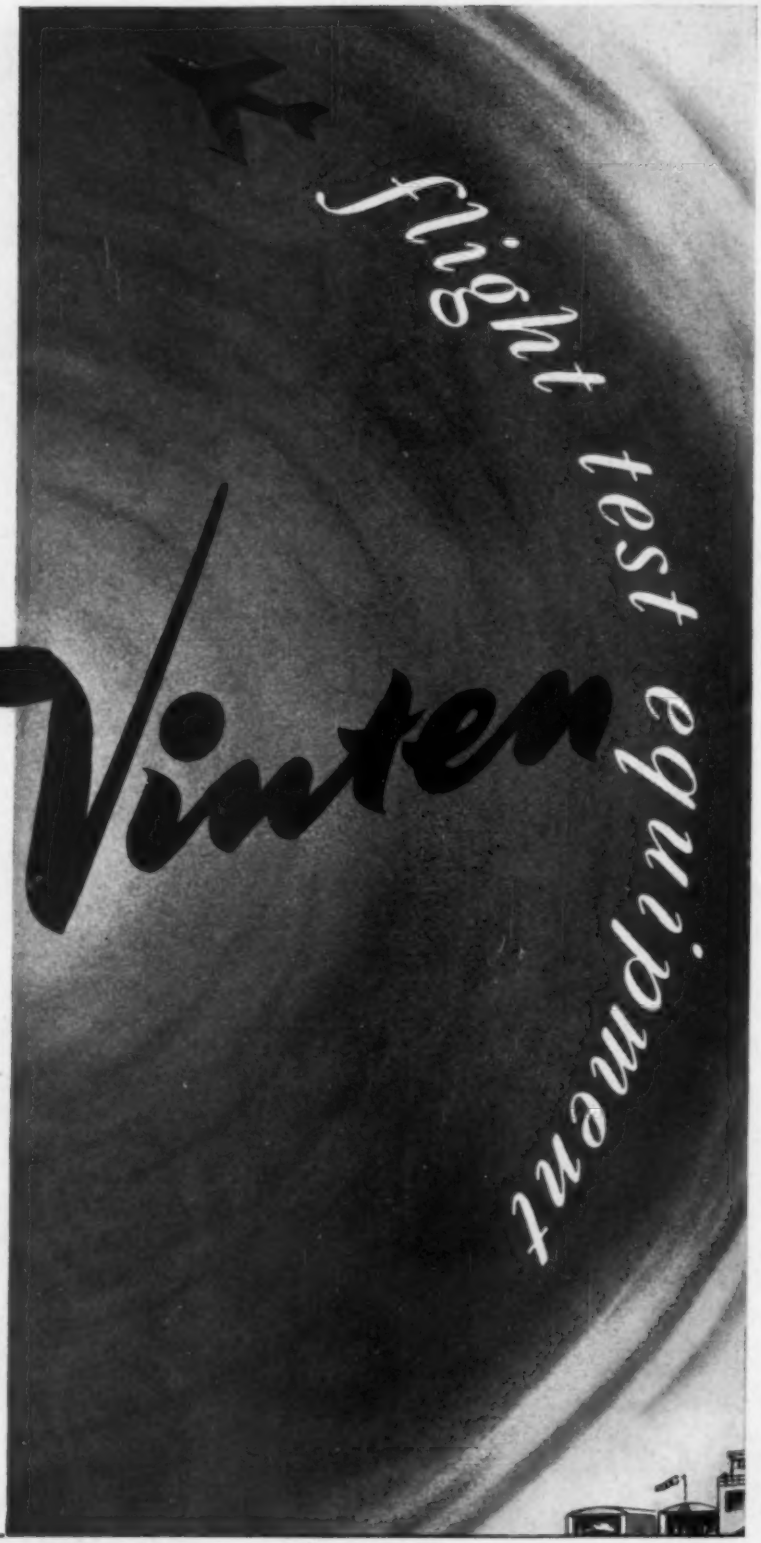

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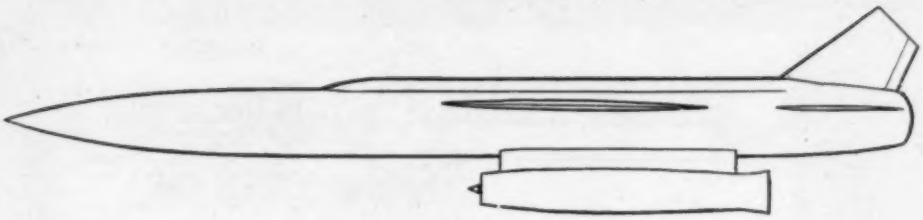


Bomarc. SAM with two 28in ramjets; take-off boost by liquid-propellant boost rocket. Length, as shown without boost, 39ft; span, 19ft; weight, 5,000 lb (8,500 lb with boost); cruising speed, M=2.5; range, 250 miles.

Guided Missiles 1956 . . .

(United States of America—continued)

Dr. W. B. McLean, now the technical director, in working out the essentials of the weapon between 1948 and 1952. Throughout, the keynotes were simplicity of design, ease of manufacture and use, and minimum maintenance requirements.

Within these limits a very effective, and remarkably cheap, missile has been designed. When development was well advanced the Navy brought in the Philco Corporation, whose Government and Industrial Division, at Philadelphia, was charged with the task of engineering AAM-N-7 for production and then building it. Named after a desert rattlesnake—which, says the Navy, is likewise "fast, deadly and uncomplicated"—Sidewinder went into production, to BuOrd contract, in 1954. Deliveries began early in 1955.

The body of Sidewinder is formed by joining cast magnesium cylinders, each of which has a particular function. At the front is the infra-red detection unit, guidance system and servos which pivot the delta-shaped controls. Next comes the warhead and finally the solid-propellant motor. Along the top are four forged lugs which slide in the shoe of the launcher. The large fins are fixed. Philco recently stated that Sidewinder had "few moving parts" and "no more electronic components than an ordinary radio."

Although the original 1953 scheme was that the missile should be carried in groups of three on a fighter's wing tips, the first machine to be armed with the missile—the F9F-8 Cougar—carries either one or two under each wing. A picture (p. 897) shows the installation on this aircraft. Service trials have emphasized what an admiral has called "the uncanny accuracy" of Sidewinder. It is claimed to "lock on a smouldering cigarette at 100 yd" and to have knocked the incendiary flares off the wing tips of F9F drones without destroying the drones themselves. It has been fired by Cougars at heights around 50,000ft, and is shortly to be evaluated against the rocket-propelled RP-70, which is capable of Mach 0.9. By the end of October, fighters of the 6th and 7th Fleets were fully equipped with the missile.

Early this year, when Philco were in bulk delivery, General Electric were brought in as a second source. Curiously, this was the first contract received by this company for missile production, notwithstanding their vast missile development experience. Sidewinder is now being manufactured by G.E.'s light military electronic equipment department.

In October the Air Force decided to adopt Sidewinder, to augment Falcon and to serve as a missile suitable for the day fighters and fighter/bombers of Tactical Air and Air Defense Commands. Designated GAR-8, a special variant is now being made for this new role. As contracting agent, the Navy awarded two new contracts, combining their requirements with those of the Air Force. The contracts for guidance and control units were £5m for Philco and £6.1m for G.E. Bulk production for both services is lowering the cost below the original estimate, already at the fantastically low figure of "under £1,000."

Skokie. Skokie I and II are both supersonic air-to-air missiles being developed for the Air Force by Cook Research Laboratories.

Sparrow. Operational with the U.S. Navy since 1955, Sparrow is one of the most effective AAMs currently in service. It is now used in more parts of the world than any other missile.

From the earliest days of the project the chief contractor has been the Sperry Gyroscope Co., of Great Neck, Long Island. Work began in 1946-7 on a BuAer (not BuOrd) study contract named Project Hot Shot. Sperry were given full responsibility "to create an entire new air-to-air missile system, suitable for multiple launching from fighters." Test firings began in 1947 and over one hundred different designs were investigated in actual trials before the eventual Sparrow I was evolved in 1951. Several combinations of firms are stated to have made early Sparrows, but Sperry has remained prime contractor.

By the end of 1952 Sparrow I, designated XAAM-N-2, was fit for production. Bulk orders were placed and a new plant, the Sperry-Farragut factory, in Bristol, Tenn, was tooled for production. Second-source production was subcontracted to Douglas Aircraft, at Santa Monica. The basic weapon is eminently clean, and has no booster. The body is built up from standard cylindrical light-alloy sections—warhead, guidance, controls, powerplant and rear guidance—and has a fine profile. The missile is steered by the pivoting wings, which give very fast response. The rear fins are fixed into slots in the cast rear body. All eight double-wedge aerodynamic surfaces are made by Kaiser Aluminium, whose precision die-castings require no machining. The solid-propellant motor is by Aerojet-General.

In April 1954 the AAM-N-2 was described by the Navy as "sufficiently reliable for Service use." Extensive trials from squadron aircraft had shown that it was an effective air-to-air weapon, and that it took less time to convert pilots to use it than to train them to shoot with conventional armament. Although only an interim stage, the missile was found to be "exceedingly formidable, with a highly lethal warhead, well-developed guidance and high reliability." It is a beam-rider.

Production Sparrows were issued to both Pacific and Atlantic Fleets in the first three months of this year. Many squadrons are now armed with the weapon and have worked up to a high efficiency. Although much of the development was conducted with such machines as the F3D Skynight, the most important Sparrow-armed aircraft in Fleet service are the F7U-3M Cutlass and the F3H-2M Demon, the latter now joining squadrons. Both machines carry four Sparrow Is on slab pylons under the wings, those of the Cutlass being toed in towards the aircraft centre-line (picture, p. 897), to assist in "gathering" the Sparrows into the beam. Current Sparrows are painted white to match the revised Navy aircraft colours; earlier deliveries were black.

Sparrow III. Offspring of the original missile are the Sparrow II (XAAM-N-3) and Sparrow III (XAAM-N-6). Development of the latter was assigned to the Raytheon Manufacturing Co., whose first £715,000 contract for research was placed in October 1954. Sparrow II was not built in quantity and Sperry-Rand are scheduled to phase out the original Sparrow I next year. When this happens Raytheon will move in as managers of the plant in Bristol and start making Sparrow IIIs. The new version has fully active homing and is therefore capable of greater accuracy at longer ranges.

Eighteen months ago, when it appeared that their indigenous missile would not be acceptable, the Royal Canadian Air Force turned to Sparrow as a missile suitable for the CF-100. Plans have now been completed for the manufacture of Sparrow III in Canada. Avro Aircraft is overall manager, Canadair is in charge of the airframe, and electronic guidance equipment is the responsibility of Canadian Westinghouse, at Hamilton, Ontario. Between £3.5m and £4m has been allocated to the programme in the current financial year.

SURFACE-TO-AIR

Antis. No task for a missile seems more difficult—even impossible—than the interception of an ICBM. The ballistic-missile warhead is relatively small and forms a poor target even for the most sensitive radar as it plunges down from 800 miles above the earth. It emits no radiation or other signals which could be detected. Above all, it approaches its target at a speed of some three miles per second.

Yet, to talk to some American engineers, one would think that the ICBM had been specially thought up in order that they might make it look a waste of time. For one thing, they argue, a ballistic missile will fly for half an hour, and its very altitude brings it rapidly into radar view, perhaps at a range of 300 miles. The remainder of the problem can then—it is said—be solved by an automatic system which can fire the Anti (pronounced aunty) at the last possible moment. The Anti is a fiercely performing SAM with a high weight/thrust ratio and a nuclear warhead. Groups are fired to meet the oncoming missile at from 250 to 150 miles from the point being defended. The temperature of the nuclear bursts is expected to prove the last straw for the ICBM warhead and re-entry body.

The Air Force request for £12.3m for this work was severely pruned by Congress, and Army Ordnance consider themselves ahead. The following are some of the firms involved in Antis:—

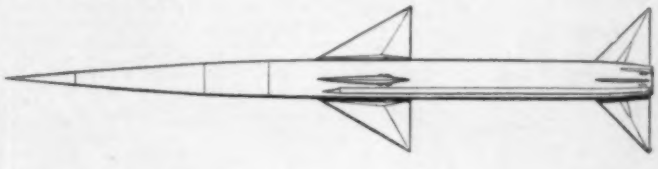
Bell Telphone Labs: possibly the furthest-advanced of all Antis; Army Ordnance £4.5m contract, hardware 1956; also Air Force study contract for similar idea. *Convair:* prime Air Force contract for one Anti. *Cornell Laboratory:* Army Ordnance study contract. *North American:* Air Force contract, study phase late 1955, hardware 1956. *Syvania,* Electronic Systems Division: one prime Air Force contract, one sub-contract to Convair. *Waltham Laboratories:* prime systems contract for DICBM (detection) monitored by Rome Air Development Center and prime Army Ordnance contract for complete Anti-system, including detection equipment and weapons.

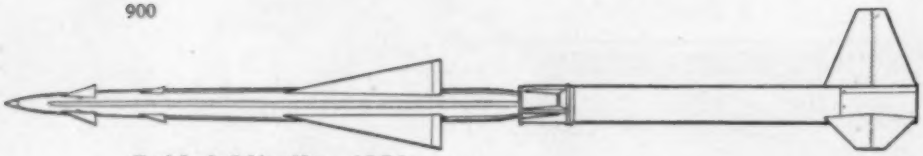
Bomarc. As big as a small fighter, Bomarc is a frightful weapon for any bomber to encounter. Alone among interception missiles Boeing's weapon flies like an aeroplane and banks during turns. The difference is, it does it quicker than the eye can follow.

The curious name is a syntheais of **Boeing** and **Michigan Aeronautical Research Center.** The latter establishment, now under a different name, was one of the first agencies to investigate complete weapons systems, and worked on Project Wizard, a 1947 surface-to-air missile. Meanwhile, the Boeing Airplane Company, at Seattle, had in 1947 begun an extensive programme upon the characteristics of ramjets. The latter soon crystallized as Project GAPA (ground-to-air pilotless aircraft) and, although inter-Service disputes set the schedule back by two whole years, hundreds of test vehicles were fired in desert proving establishments and good results were obtained.

By 1951 Boeing had obtained Air Force support for a complete

Sparrow 1. AAM with solid-propellant motor; no boost motor. Length, 8ft 4in; span of movable wings, about 21in; body diameter, 6in; weight, 295 lb; burn-out speed, M=2.7; range 5-7 miles.





Nike Ajax. SAM with tandem solid-propellant boost motor and liquid-propellant sustainer. Basic missile length, 20ft; overall length with booster, 35ft; wing span, about 4ft 9in; body diameter, 12in; weight without boost motor, 1,500 lb; burn-out speed, M=2.1; max. slant range, 18 to 23 miles.

Guided Missiles 1956 . . .

(*United States of America—continued*)

defence system based on a large SAM powered by two ramjets, and with a range many times greater than that of any other anti-aircraft weapon. With the designation F-99, work advanced rapidly in the company's Pilotless Aircraft Division. The Division's facilities at Seattle were expanded at the end of 1954, when well over 2,000 were wholly engaged in Bomarc development. Responsibility for propulsion had then for many months been assigned to Marquardt, at Van Nuys, Cal., the prime contractor having tapered-off work in this field.

By 1955 the whole programme had been clarified, and the eventual weapon system for the missile could be seen in detail. The prime contractor's responsibility was extended to include the entire system, comprising the missile, bases, logistics, communications and maintenance. By November, however, Boeing were given instructions to concentrate more intensively on the basic missile (which had then been redesignated IM-99), systems responsibility for certain guidance and ground-environment equipment having been transferred to a New York consultant firm. Actual development and system-engineering for the guidance and control equipment was assigned to the Westinghouse Electric Corp., at the Air Arm and Electronics Divisions in Baltimore.

As the drawing shows, Bomarc houses everything but propulsion in its mighty cylindrical body, which is built like a fighter and embodies area-rule principles. At the front end is a homing guidance package and a huge warhead; Rheem's research and development laboratory is working on the latter and there is a strong possibility that it may be of the nuclear variety. Most of the interior is full of kerosine fuel, contained in tanks formed by complete body sections. The comprehensive accessory systems are energized by a self-contained source of shaft-power, probably to be a Kidde mono-fuel turbine in production Bomarcs. Some Bomarcs launch Falcons, and are themselves recoverable.

Cruise propulsion is provided by a pair of Marquardt MA-20C ramjets carried on pylons attached to strong fuselage frames. Each has a diameter of 28in, weighs some 490 lb and delivers about 10,000 lb thrust at Mach 2.5/3, equivalent to about 50,000 h.p. Fuel is fed by pumps driven by the shaft-power unit and is metered by a fuel-control package which is programmed to suit a boost period of up to 45 sec. The boost for launching is provided by a single, very large Aerojet-General solid-propellant rocket.

Early in 1955 Bomarc was reported "in considerable system-development trouble, although its components have good reliability." In April of that year, Gen. Twining, then Air Force Chief of Staff, said "we are pleased with results so far," and successful firings of development vehicles were reported from Patrick A.F.B. in the same month. This year complete IM-99s have been launched at the rate of about one every two weeks, and in January it was stated that accuracy was "better than expected." The complete "business end" was test-flown in a Lockheed F-94B, a flying test bed used "for the development of air-defense missile systems." Free firings showed that the slant range was about 200 miles, with complete reliability. The design figure was 250 miles, and it is hoped that 300 will be achieved by the time IM-99 joins the U.S.A.F.

In service it will form special squadrons of Air Defense Command. The missiles will be stored in tiny hangars "near the likely approach paths of raiding bombers." Upon receipt of an early-warning signal the missiles would be run out on to their launchers, the boosters attached and checks completed in a matter of minutes. No details are available regarding the control available after launching, the type of guidance or the precise operational method of employment.

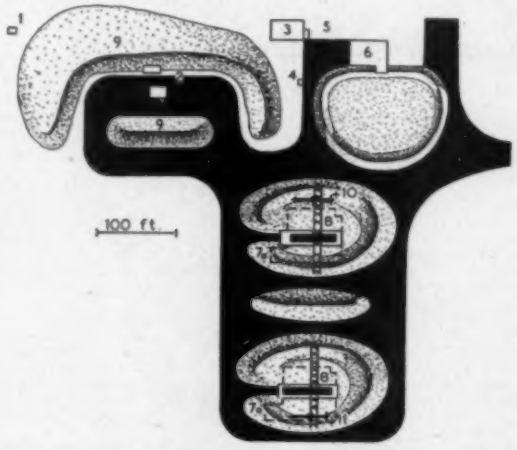
Boeing are now searching for somewhere to build Bomarc in quantity. In July the Air Force voted £1.5m for facilities for production at Seattle, but it has long been believed that the company's Wichita, Kan., plant was the eventual choice. Recent increase in B-52 production to 20 per month, plus the announced difficulty of re-tooling Wichita for the missile, are bringing about a change in plans. Sites investigated include a location in Salt Lake City; the Ford Motor plant in Richmond, Cal.; and the Chrysler-owned facility in San Leandro, Cal.

Hawk. Generally regarded as a supplement (not a replacement) to Nike, this missile is being rapidly developed to Army Ordnance contract by the Raytheon Manufacturing Co., at Waltham, Mass. It is specifically intended for employment against aircraft or other targets at all altitudes down to ground level—a factor in which many existing SAM systems fall short of the ideal.

Hawk is powered by a single liquid-propellant motor and has an announced range of "up to 50 miles." A snippet of news is that "Diversey Engineering Co., Franklin Park, Ill., make high-alloy-steel bulkhead sections and radome moulds" for this missile. The production stage was reached early this year.

Loki. A standard Army Ordnance "barrage-type" anti-aircraft weapon, this simple solid-propellant, spin-stabilized rocket has no guidance. About 6ft long and of 76 mm (3in) calibre, it was developed by East Coast Aeronautics and Grand Central Aircraft (motor) and is made by Bendix. The original design was based on the German "Taifun," and Loki went into production late in 1954.

Nike. Probably the first surface-to-air missile anywhere in the world to go into wide service, Nike (the currently operational version is known as Nike Ajax and bears the A/N code SAM-A-7) has a history which goes back to the immediate post-war years. The basic conception was planned to meet the possible threat of bombers of the calibre of the Tu-4 (B-29) on a one-for-one (one Nike kills one bomber) basis. Although it was considered that Nike would also be effective against first-generation jet bombers, on a three-for-one basis, it has never been regarded as more than an interim weapon.



Nike launching site: 1, Acid store; 2, acid fuelling; 3, electric generation; 4, JP-4 fuel pad; 5, transformer pad; 6, Nike assembly/test; 7, frequency changer; 8, underground Nike store; 9, 8ft blast moulds; 10, 11, launchers. The site pictured on p. 893 has six launchers.

Nevertheless, to start early is to reach an advanced stage of development early, other things being equal; and when, in 1953, the Army were spurred by Korean fighting into ordering an anti-aircraft missile in bulk, K. T. Keller, then head of the guided missiles office at the Defense Department, recommended Nike as "the best production weapon." This decision was momentous; but it is too early to say whether it was right.

Although obsolescent, Nike is a remarkable weapon. Most of the airframe is assembled from precision die-castings or forgings needing no machining. Sustainer propulsion is provided by a single liquid rocket running on red fuming nitric acid and petrol; launching is effected by a single large booster with a solid filling, contained in a casing fitted with large stabilizing fins spaced at 120 deg. Steering is effected by the delta nose-controls, the rear sets being for stability only.

Nike's weakest link is its guidance system. Launching is substantially vertical to the burn-out point of the booster. The latter is then dropped and the missile is steered sharply towards its target under command guidance from the ground. The remainder of the flight is governed by a lead beam which follows tracking radars locked on to the target. Ground computation then so controls the lead beam as to bring the missile to a pre-calculated position in space just ahead of, and below, the target. The warhead is then detonated by an auto-command signal, the target running into the resulting lethal spray of fragments. Operational slant range varies from 18 to 25 miles, the flight time being 80 to 110 sec.

There are manifold weaknesses in such a system. From the point of view of the taxpayer, it is unfortunate that it necessitates a complex ground-control system, in this case known as the Missile Master. Developed principally by the Martin Company, this equipment comprises an electronic system for the co-ordination and direction of a large number of firing batteries, with human supervision imposed at critical points. Such a system is obviously essential, and it must also tie each battery to the Semi-Automatic Ground Environment (SAGE) system; but Nike's characteristics are such that more ground gear is required than would be necessitated by later, fully homing missiles.

Nike is susceptible to countermeasures, and its range is so short that it can barely reach a jet bomber before the latter releases its load at the area being defended. Furthermore, last-minute evasive action by the target can increase the miss-distance sufficiently for the chance of a kill to be remote. Yet other disadvantages are that the control system is not well suited to solving the problem of engaging two targets flying close together; and tracking radars have to follow each missile all the way to the target. It can also be argued that Nike is expensive in relation to its killing power; each missile costs some £10,000 and guidance equipment is reported to cost £300,000 to each site. But it is better than nothing, which was the alternative.

The start of the Nike programme was the placing of an Army Ordnance study contract with Bell Telephone Laboratories in 1945. It called for an evaluation of the problems involved in the design of "a controlled anti-aircraft rocket." By the first half of 1946 a fairly simple missile had been sketched, with a performance adequate for the piston-engined threat of that time. Originally there was a cluster of four booster motors, but these were replaced by one large booster during early, unguided, firings at White Sands in 1946. It was in this year that Douglas were brought in as manufacturers of the missile and launcher. Western Electric were assigned the major electronic burden,

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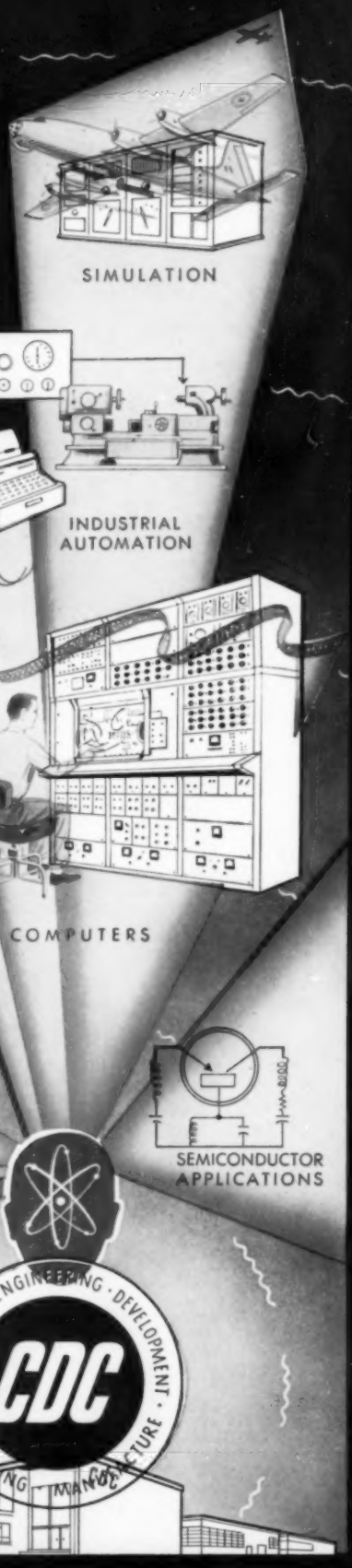

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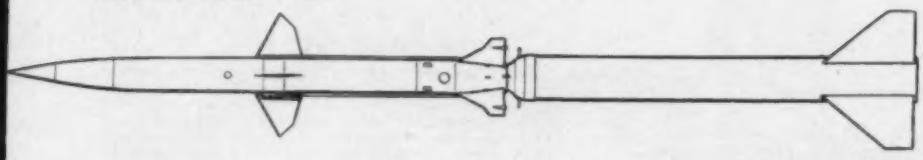


Terrier. SAM with tandem solid-propellant boost motor and solid-propellant sustainer. Basic missile length, 12ft 11in; overall length with boost motor, 26ft 11 in; wing span, 3ft 2in; body diameter, 11 in; weight with boost motor, reported to be 3,350 lb; speed at burn-out, M=2.5; max. slant range, 20 miles.

Guided Missiles 1956 . . .

(*United States of America—continued*)

although trials with guidance did not begin until 1951.

For several years the prime contractor has been Western Electric. Major subcontractor is Douglas Aircraft, whose Santa Monica division has assembled the bulk of the "several thousand" Nikes so far delivered. This year Douglas also began deliveries from a government-owned plant in Charlotte, N.C. There are over one thousand sub-contractors. Since the end of 1955 Hamilton Standard has been a major airframe sub-contractor, joining Kaiser Aluminium (who die-forge major portions within 1/32in), Menasco (who weld-up the 12in-diameter air tanks) and Rheem (whose Downey plant makes fins, centre and aft body, fuel hoppers and propellant pressure-vessels). The guidance system is shared by the prime contractor and Bell Telephone Laboratories.

Responsibility for the sustainer motor is shared by Aerojet-General and Bell Aircraft. Rated at 2,600 lb at 10,000ft, this single-chamber unit runs on RFNA (red fuming nitric acid) and jet fuel, fed through external pipes by stored air pressure. Early motors were regeneratively cooled, but when Bell were brought into the picture (in 1953) they evolved an uncooled chamber lined with Niafrax A ceramic. The resulting chamber fits an envelope 18½in by 6½in diameter and weighs 20 lb; combustion conditions are 5,000 deg F and 330 lb/sq in absolute. Maximum firing time is 35 sec (greater than previously), specific impulse is 212 and efficiency 97 per cent at 60,000ft. The larger booster is a product of the Hercules Powder Co., of Wilmington, Del., with further deliveries from the Army Ordnance plants at Lawrence, Kan., and Radford, Va. Most of the booster cases so far delivered have been formed from high-tensile sheet steel, wrapped and welded by Goodyear. These cases were dangerous to friendly property, and they are being replaced in production by frangible or consumable cases.

First tests of Nike against target aircraft took place at White Sands in January 1953. Within the first few months several drones had been destroyed, most of them QB-17s flying straight and level at about 30,000ft at 220 knots. The complete missile system first became operational in December 1953. Forty sites were authorized in that year, and in the following May 14 were being equipped, the first to reach combat status being around Washington, D.C., and Los Angeles. Early in 1955 more than 100 sites around 13 cities had been activated, and appropriations in the last two fiscal years have brought the total Nike bill to £316m. Nike was evaluated in the Arctic in November 1954, by Canadian Service teams. Trials have been made in competition with other missiles, and Nike has shown a fair ability in destroying jet-propelled targets (although small drones have often flown between lethal fragments unscathed).

A diagram (p. 900) and photograph (p.893) give an indication of the geometry of a Nike launching site. Several such sites are stationed around each area to be defended, covering the sky up to 60,000ft within a circle 25 miles in diameter. The batteries are arranged in groups of up to four from 1,000 to 7,000yd apart. As the diagram shows, underground magazines (62 by 58 by 12ft) are provided for storing the missiles. The battery control area, some thousand yards distant, has three radars, for acquisition, target tracking and missile tracking. Each battery can handle up to six quadruple launchers, as the picture proves; normally, however, there are two, and the personnel strength per battery is then 108, with a monthly payroll of £9,700.

Nikes fired in service have generally been in store about three years, so their mean operational reliability of 95 per cent is excellent. Their kill probability (per missile) is reckoned "better than evens" against typical targets.

Nike Hercules. Previously designated Nike B, this missile is appreciably more potent against the type of target with which it is most likely to be matched. There have actually been several development stages, an intermediate stage being Nike II, which did not go into production.

Gen. Maxwell Taylor, Army Chief of Staff, recently spoke of "four- and six-cylinder types under development," apparently referring to the number of boosters employed. Another report describes Nike as "the beginning of a family which represents a real hope for an effective element of air defense." Nike Hercules is longer than its predecessors, the missile itself measuring some 25ft. Marked improvements in motor power and efficiency are claimed to have increased the maximum slant range to over 40 miles. Nike Hercules will also be able to have a nuclear warhead, Rheem being responsible for developing this component.

Unfortunately, the new weapon cannot "effectively utilize all the Nike fixed bases in the United States"; and according to the Air Force, it requires a new launching system, although the Army Secretary denies this. An unofficial report also avers that Western Electric have "recommended that the Army switch from command guidance to target-seeking guidance." Recent Army testimony announced that "the present Nike can operate against supersonic targets and Fiscal Year 1957 makes provision for a superior supersonic missile of the Nike type capable of destroying such targets." The very great increase in Army missile appropriations in 1957 is partially ascribed to "completion of development of Nike B earlier than expected. This re-programming will put this major improvement into the hands of our presently operational anti-aircraft units a full year ahead of schedule."

Shrike. Little is known of this weapon. It is reported to be an Air Force SAM, developed by Bell—almost certainly Bell Aircraft—with a liquid rocket (probably also of Bell design and manufacture).

Talos. It is stated in the description of Terrier that that weapon was evolved as an off-shoot from Project Bumblebee, a study for a guided anti-aircraft rocket begun in 1945. The Applied Physics Laboratory of Johns Hopkins University, Baltimore, were the contractors to the U.S. Navy on this project.

Talos is the first true Bumblebee end-product (another is the much larger Triton). The original 18in-diameter ramjet was flown in 1946, and Mach numbers of 2 were soon being recorded, using kerosine. Many hundreds of test vehicles eventually led to the perfection of an efficient ramjet, with a double-shock intake, together with a reliable fuel system capable of taking the shock of the rocket-boosted launching. The control configuration is very similar to that of Terrier, apart from the fact that the pivoting wings are closer to the stabilizing tail fins. The body is also relatively fatter, containing as it does the integral ramjet.

Prime contractor for Talos is the Missile Division of Bendix, at Mishawka, Ind. Principal sub-contractor is McDonnell Aircraft, at St. Louis, whose responsibility has been the powerplant. Guidance has been handled by the Farnsworth division of International Telephone and Telegraph, this equipment being housed—with the fuel and warhead—in the annular space left between the ramjet duct and the exterior skin. Additional equipment, including ramjet controls, is located inside the intake centre-body. The solid-propellant booster shown in the drawing may not be that employed in the bulk of production rounds.

There have been several development stages of Talos, two of which are distinguished as Talos L and Talos W. All carry the Army/Navy designation XSAM-N-6. The first production rounds in 1955 cost roughly £70,000 apiece, but the price is dropping rapidly as Bendix increase production. The design range is about twice that of first-generation rocket SAMs. In October Admiral Arleigh Burke, Chief of Naval Operations, announced that service-test Talos missiles had scored six consecutive hits on airborne targets at a slant range of 37 miles—a factor which indicates that the guidance system must be appreciably more advanced than the beam-riding of Terrier.

One light cruiser is at present being converted to include Talos armament, under money voted in the 1956 appropriation. Three Talos-armed ships are to be commissioned by 1959, five by 1960 and eight by 1961.

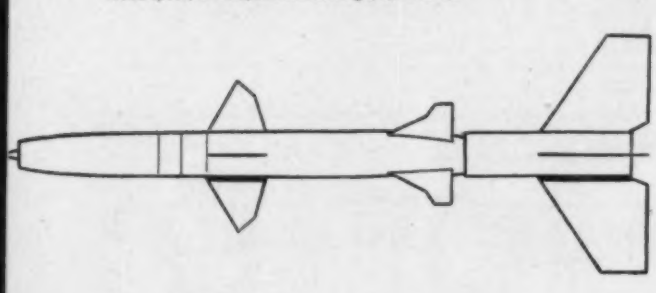
Since the end of 1955 Talos has publicly excited the interest of both the U.S.A.F. and U.S.M.C. The Air Force have sponsored a programme for the development of a land-based derivative, with the Radio Corporation of America acting as prime contractor. An advanced, long-range version has been sought by the Air Force since May. In particular, Strategic Air Command wish to defend their bases with this missile, starting with four of the most important fields in the U.S.A. and finally including S.A.C. bases in all parts of the world. Although a sum of £5.7m. has been agreed as an allocation for site construction, further Air Force—and, presumably, Marine Corps—appropriations are blocked pending the outcome of competitive trials with Nike and clarification of rôles.

Tartar. In its essentials this missile is a refined and improved Terrier (described later). It has been adopted by the U.S. Navy as a standard anti-aircraft weapon.

Basic development was carried out by the Johns Hopkins APL (as was that of Terrier), and Convair are again the prime contractor. In appearance the missile resembles an improved, and (at 12ft) rather smaller, Terrier, and it is launched without a booster. It is claimed to beat Terrier's performance, and is described as "proportionately more powerful." A very valuable advance is the inclusion in Tartar of a homing head.

Tartar came into pre-production—in America this probably means more than a dozen rounds per week—at Pomona during the past few months, and in full production is expected to cost not more than £3,500-£4,300. The Navy have decided to employ it as standard armament on several destroyers and as secondary armament on cruisers and capital ships, replacing 5in guns in each case. Eight destroyers

Talos 1. SAM with tandem solid-propellant boost motor and integral ramjet sustainer. Basic missile length, 10ft; overall length with boost motor, about 15ft; wing span, 4ft; body diameter, 18in; weight with boost motor, over 2,500 lb; cruise speed, M=2.5; max. slant range, 42-45 miles.



Guided Missiles 1956 . . .

(United States of America—continued)

are to be converted, with money from the 1957 programme. These will all be commissioned by 1960, and they will be joined by nine further vessels, of unstated type, by the following year.

Terrier. There is some justification for assessing this ship-based missile as the most effective anti-aircraft weapon at present in service anywhere. It is a standard Fleet-defence weapon of the U.S. Navy and has also been adopted by the U.S. Marine Corps.

Like Nike, Terrier's story can be traced back to 1945. In that year the U.S. Navy, somewhat shaken by the Japanese *Kamikaze* assaults, put out research contracts for a ship-to-air missile. The Bureau of Ordnance requested the Applied Physics Laboratory of the Johns Hopkins University to do the job, which went ahead as Project Bumblebee. Over the ensuing years many hundreds of test vehicles, with ramjet propulsion, were fired; much of the effort was expended in arriving at a suitable ramjet.

Many of the test vehicles employed in stability and guidance trials were powered by rockets, and it was soon obvious that, if such propulsion were used in place of a ramjet, a reasonably useful missile could be made available relatively quickly. This was done, and the lowly test vehicle—with beam-rider guidance—branched out into the complete Terrier weapon system, the missile itself being SAM-N-7. Convair was brought in as manufacturer, under the tutelage of JHU/APL. The Navy built a completely new production plant at Pomona, Cal, and Convair began deliveries from there in January 1953.

Terrier's configuration is almost a classic form for anti-aircraft missiles. At the front is the warhead, with its very heavy charge, fired by a proximity fuse, and surrounding fragmentation unit. At the rear of this section is the forward guidance package, containing hydraulic servos and carrying the four pivoting wings (as noted elsewhere, the response from pivoting wings is more rapid than from tail controls). Further aft is accommodated the solid-propellant sustainer and the aft guidance assemblies, including the four fixed fins with their rearward-facing aerials for riding the beam. The fins are indexed at 45 deg to the wings. Finally there is the 14ft booster, which develops 200,000 h.p. at burn-out.

Convair's production, and second-source manufacture by Motorola, at Phoenix, Ariz, is supported by a host of sub-contractors. High-precision magnesium and aluminium die-castings are made by the Harvill Corporation; sustainer motors, which are claimed to burn longer than do the liquid-propellant units of the earlier Nikes, are produced by the M.W. Kellogg company; the boosters were developed by the Alleghany Ballistics Laboratory and Philco were responsible for the proximity fuse.

Most of the development for initial service took place between 1951 and 1954. A variety of drones, up to the size of P4Y-2Ks, were successfully destroyed, intensive Fleet firing starting in 1952. The first ship to fire the weapon was U.S.S. *Mississippi*, which took part in Atlantic Fleet exercises with Terriers in November 1954. By this time work was well advanced on the conversion of the first Terrier-equipped fighting ship, the cruiser *Boston*.

It has been written that missile equipment "fills Boston from keel to top-sides aft of funnel." Whole areas are devoted to Terrier storage, assembly, mechanical feeding to the launchers and firing. There are two superimposed twin launchers, each governed by ship radar installed by Reeves. The latter equipment comprises AN/SPQ-5 tracking and guidance radar and AN/MSG-3 fire-control equipment. The whole system is completely different from the land-based, area-defence Nike. The ship commissioned in the spring of 1955, joining CAG-1 with a complement of 1,635 including 103 missile technicians.

During several series of operational trials under war conditions *Boston* has proved the capability of the Terrier system. The brain of the MSG-3 gear decides which target will be engaged and prepares the system for firing. The launchers are aligned fore-and-aft at 90-deg elevation, ready to receive the missiles. The latter, with boosters, are hydraulically rammed up the rails of the feedways and on to the adjacent rails of the launchers. The launcher then follows the locked-on beam until the missiles are fired, normally two in a salvo, with a slight time-difference. The Terriers are gathered into the beam and ride a curve of pursuit to the target, reaching Mach 2 in the 3½-sec boost period and then accelerating more gradually to Mach 2.5. It has been found that *Boston* can track two targets at once (one per launcher) and that the pair of twin-launchers can sustain eight rounds per minute indefinitely. Target drones travelling at "over 500 kt at around 50,000ft" have been destroyed without difficulty. The only real operational trouble is that the beam-riding system cannot be depressed sufficiently to counter a wave-skipping attacker.

In May a second Terrier-cruiser, the *Canberra*, was commissioned. She differs from *Boston* in her guidance radar. A destroyer is being converted on the 1956 budget, and the total of Terrier-equipped ships is scheduled to reach four by 1959, 13 by 1960 and 22 by 1961. By the latter year, however, Tartar (q.v.) should be in service. The first production Terriers cost some £10,500 complete with booster, and the price is now slightly lower as deliveries increase. Production rounds are delivered by rail to depots on the Atlantic and Pacific coasts, there to await delivery to the Fleet by special replenishment craft.

In the 1955 fiscal year the U.S. Marine Corps decided to buy Terrier as a standard weapon for the protection of assault troops. A first appropriation of £1.13m was made for 275 missiles, and it was stated that 485 Terriers would "only partially fulfil the first-year mobilization requirements for one Terrier FMF battalion." The U.S.M.C. have evolved a variety of special ground equipment, vehicles and mobile twin launchers.

AIR-TO-SURFACE

Bullpup. This is the only Navy air-to-surface missile at present in advanced development. The Martin company have been prime contractors since the project contract was placed in the autumn of 1954.

Bullpup is a straightforward-looking missile, 11ft long and 1ft in diameter. It is powered by an Aerojet-General solid-propellant motor and has a canard layout with delta controls forward and trapezoidal wings at the rear. In July 1955 it was claimed that its growth in development had been so great that it was to be re-designated Bulldog.

Crossbow. Developed as a system for the Air Force by Radioplane—the Northrop subsidiary responsible for many drones and targets—Crossbow is a relatively simple weapon. It is subsonic, with turbojet power, has an aircraft-type configuration.

Flight-test vehicles were evaluated in the summer of 1955 at Holloman, and a complete MX-2013 Crossbow was flown for the first time last July. The missile may be manufactured at the new Northrop facility north of El Paso, Tex.

Dove. Although its development is not particularly recent, no illustrations have yet been released of this Navy AUM. Originally styled XASM-N-4 it was recently redesignated AUM-N-4, presumably indicating such a change in function. Dove development has been in the hands of Eastman Kodak. A heat-seeker, it is intended for use against surface and underwater targets, and was reported to have entered production last year.

Goose. This aircraft-shaped missile is apparently capable of use as either an SUM or an AUM. Sponsored by the Air Force, it is a Fairchild product, the prime contract being held by the company's aircraft division and the guided-missile division being responsible for guidance. Power is provided by a 2,000 lb-thrust turbojet of either Fairchild J83 or G.E. J85 type. Goose has a long range and is well advanced in flight tests.

Lulu. This is the most potent weapon yet devised for killing undersea craft. An AUM, it is fitted with a nuclear warhead, with a lethal underwater radius "measured in miles." The Navy BuOrd and specialist agencies have developed Lulu since 1954, and the missile is assembled by the Sandia Corporation, at Albuquerque, N.M.

Minneapolis-Honeywell. The first guided-missile prime contract awarded to this company is for an Air Force ASM. The contract, which is shared by the company's aeronautical and ordnance divisions, calls for a missile capable of "peeling back to the target" after the mother aircraft has made a high-speed run over it.

Petrel. Reminiscent of early German missiles, Petrel (AUM-N-2) is nevertheless very effective. It is the nearest approach yet to a "winged torpedo," for that is what it is.

Development was carried out for the Navy BuOrd by the National Bureau of Standards. Starting with a standard 24in Mk 13 torpedo, N.B.S. added a wing, a twin-finned tail, a nose guidance package and a turbojet at the rear. The added airframe is a conventional stressed-skin structure, apart from the fins which are each formed from a pair of pressed skins filled with metal-bonded honeycomb.

Petrel is carried by a large machine like the P2V-6B, P5M-2B or a developed HSL helicopter. It is launched outside the defensive range of an enemy fleet, towards which it flies under the guidance of a fully active homing head in the nose package. Near normal torpedo range the height is checked by a radar altimeter beneath the nose and, at the correct position, the airframe, powerplant and other additions are jettisoned. The bare torpedo then runs home conventionally.

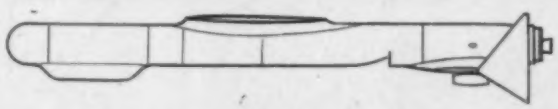
Since 1955 Petrel has been in volume production by the guided-missiles division of Fairchild, at Wyandanch, L.I. It is shipped, together with the AN/APA-80 control monitor group, in aluminium containers made by Honold. Evaluation was completed at NOTS, Chincoteague, Va, and later trials were conducted by the Fleet Operational Development Force, the J44 engines being recovered by parachute for re-use. Very satisfactory performance was announced, the Navy commenting on "a degree of reliability unusual for such a sophisticated weapon."

Rascal. Since 1948 Bell Aircraft have been evolving a supersonic air-to-surface weapon at their Niagara Falls plant. Originally designated XB-63, and now known as GAM-63, Rascal is based largely on the company's experience with the X-1 family of research aircraft.

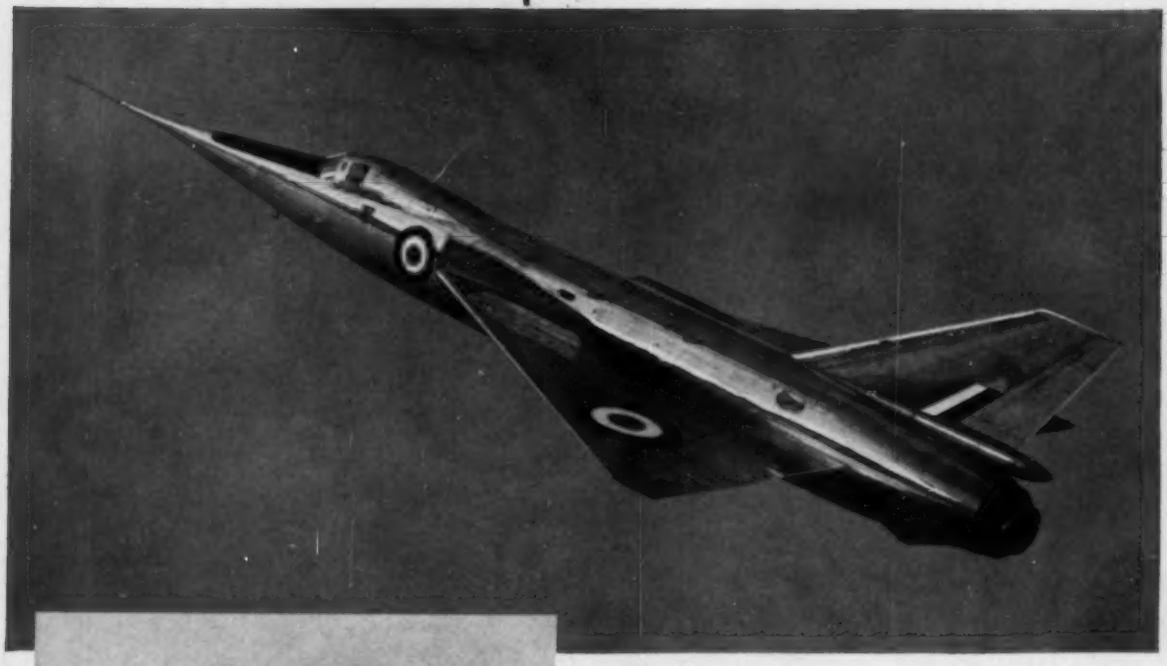
The Air Force placed the "producibility contract" in the autumn of 1952, giving Bell the complete systems contract. The GAR-63 comprises a trim aircraft-like missile, and a certain amount of equipment carried in the launching aircraft. The warhead can, of course, be of any nuclear or H.E. variety. The missile is some 35ft long and weighs 13,000 lb. It is propelled by a Bell triple-barrel liquid-oxygen motor, with aluminium chambers, and a maximum rating of 6,000 lb; cruise speed is about Mach 1.5.

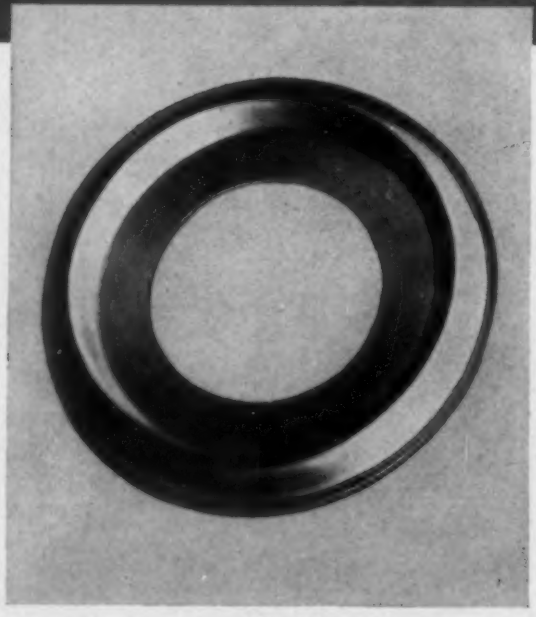
Rascal is launched in X-1 manner about 100 miles from the target. After the initial drop from the mother-ship (a B-47 or B-52) a preset programming device puts the Rascal into a climb to about 100,000ft—high enough for it to be an interception headache. Inertial and/or star tracking has been reported, but it is more probable that the mid-course guidance is effected from the launching aircraft. Maximum

Petrel. AUM with 1,000 lb-thrust J44 turbojet cantilevered at the rear and fed through a ventral intake. Overall length, 24ft; wing span, 13ft; tailplane span, 8ft; body diameter, 24in; weight, 3,800 lb; speed under power, M=0.7; operational range, over 5 miles.



Afterburners in NIMONIC alloys





Pressed ring in Nimonic 80 sheet for a Rolls-Royce afterburner.

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Guided Missiles 1956 . . .

(United States of America—continued)

speed is reached at burn-out and the terminal guidance function pushes the missile over into a step dive on its target.

In March 1954 Boeing were engaged in launching Rascal from a B-47. By March 1955 the missile was described as "very close to operations" in a report which also stated "the missile has registered hits with amazing accuracy during simulated combat conditions." In May of that year it was officially stated that GAR-63 had "achieved its programmed speed and altitude and demonstrated its ability to hit within a reasonable distance of the target." Nevertheless it must be recorded that, in April of this year, a crash-programme brought in a new guidance system, developed by the Federal Telecommunications Laboratories, at Nutley, N.J. If this system is satisfactory the missile may go into service with Strategic Air Command.

SURFACE-TO-SURFACE

Atlas. The conception of an intercontinental ballistic missile capable of reaching any point on earth is to be found in 19th-century fiction; but it is only since design-effort has actually been applied to such a weapons system that the magnitude of the task has been properly appreciated. As is noted below, the design of the missile itself has been enormously eased and accelerated by unexpected developments in the technology of nuclear warheads; but even with such fortuitous assistance, Atlas remains—it is said—the largest single design problem yet attempted by man.

Initially the programme was uncertain in the extreme and its early years were chequered by the fact that each of the Pentagon missile-survey committees between 1950 and 1953 rejected the conception as being incapable of practical realization. Nevertheless, the U.S.A.F. decided to place study contracts for such a weapon with the Convair Division of the General Dynamics Corporation, who had been at work in the field since World War 2—particularly with MX-774, cancelled in 1947. The new study was designated MX-1593; it was initiated at a time when the Atlas Corporation was Convair's controlling shareholder and it is from this that the programme received its name. Until 1954 the annual budget was less than one million dollars, and in 1953 the Secretary for Defense almost cancelled it altogether. It had a low priority and was aimed at producing a weapon "in one or two decades."

The drawing boards in Convair's San Diego plant at that time would probably have daunted the most ardent believer in the ICBM. They would have revealed plans for a three-stage missile standing about 200ft high and weighing about a ton for every foot. Propulsion in the first stage would have required seven motors each of 125,000 lb thrust, the whole cluster developing some twenty million horse-power at burn-out. Maximum Mach number would have been 15, and the peak of the trajectory 600 miles for an ultimate range of 5,000 miles. Even those engaged in its design must frequently have felt that it would never become "hardware." The customer's viewpoint (expressed by Maj.-Gen. R. S. Brentnall, Air Force Assistant Chief of Staff for Guided Missiles) was that "warhead size caused severe requirements in the areas of guidance, propulsion and re-entry which were beyond the state of the art."

Then came the break-through, two major factors working together to ease the ICBM's mighty problems. First, the size and weight of the warhead needed was so drastically reduced that, when coupled with the extreme scale-effect characteristic of such a missile, the final vehicle weighed only a fraction of its predecessor. Second, the increased megaton yield of the fusion reaction allowed for destruction of the target even in the event of a miss by several miles, and the resultant relaxation in the required accuracy of the guidance system was invaluable. Overnight the entire design began again from scratch, but this time within the limits of existing knowledge and ability.

In 1953 the Air Force set up a Strategic Missiles Evaluation Committee, and this group recommended the establishment of an *ad hoc* development management group (two Air Force offices and a civilian contractor) to oversee all such weapons. The Air Research and Development Command formed a Western Development Division, with an exceptional strength in scientists and engineers. This office has since managed the ICBM programme, and is also responsible for all Service development including the training of the final Air Force Task Group to operational capability. Purchasing and "paperwork" was assigned to the Ballistics Missiles Office of the Air Materiel Command, and the guided missile division of the Ramo-Wooldridge Corporation was hired to provide technical direction and systems engineering. Convair's position is described as "principal associate"—which initially was not well received in San Diego.

Trevor Gardner, former Air Force Assistant Secretary for Research and Development, was instrumental in activating the overall programme. At the end of last year it was accelerated and given the designation Weapons System 107A. The missile itself is SM-65A. The many thousands of scientists and engineers engaged on it have worked a 45-hr week throughout 1956.

During 1955 the essentials of WS-107A were worked out in detail. Even the ground-support devices became literally a billion-dollar business, and sufficient private firms were harnessed to ensure that the specified schedules could be met. Guidance was placed in the hands of the Arma Division of the American Bosch Corporation at Garden City, Long Island, with assistance from Bell Telephone Laboratories and Remington Rand's Univac Division. Avco's Advance Development Division was awarded contracts for the nose cone and re-entry body, with support from Lockheed Aircraft and General Electric's Missile and Ordnance Systems Department. American Machine and Foundry, Burroughs, General Electric (Heavy Military Electronics Division), Massachusetts Institute of Technology, Sperry Rand and Western Electric were also brought in for research support, and the Rocketdyne Division of North American Aviation gained the contracts for propulsion. Convair formed an Astronautics Division to handle Atlas and similar projects, and the construction of a prototype missile was started in a special part of Plant I at San Diego.

Unlike the original concept, the SM-65A is a single-stage missile. The very efficient powerplant group—under development by North American at Canoga Park—includes three liquid-oxygen motors. The main sustainer is a single-chamber unit rated at 135,000 lb thrust, and it is fed with propellants for the full 180-sec firing period. Booster thrust is provided by a pair of 100,000 lb chambers mounted in nacelles alongside the sustainer and jettisoned at the burn-out. An outstanding fuel system has now been evolved, with turbo-pumps feeding at the rate of 1,800 lb/sec, the exhaust from these pumps being burned in the main sustainer chamber.

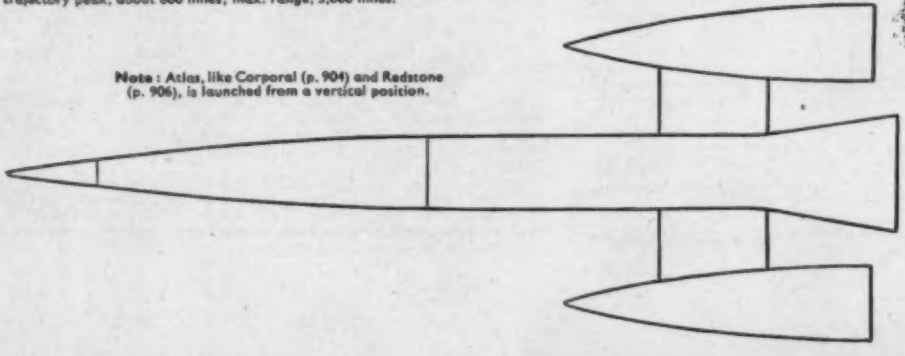
Perhaps the most difficult problems of all are posed by the re-entry, i.e., the conditions experienced by the nose and fore-body when, after separating from the remainder of the missile, it curves over from the peak of its trajectory 800 miles up and begins to plunge down into the atmosphere. Much of the early nose-cone research was conducted in tunnel E.1 at the AEDC (Tullahoma), while Avco's 100ft shock-tube has simulated Mach numbers approaching 25 at 15,000 deg F. Recent work with a large helium gun at the N.A.C.A. Ames Laboratory has taken the re-entry investigation up to Mach 30, and in 1959 the whole warhead and re-entry body is to be one of the first items tested in the mighty supersonic tunnel which should then be completed at Tullahoma. Quite early on it was found that the optimum nose was slightly blunted —a compromise between, on the one hand, skin friction and the absorption of the tremendous kinetic heating without losing too much strength, and, on the other, high wave drag involving performance reduction. It has now been found that the problem can be eased by decelerating before re-entry—by forward-facing rockets.

Notwithstanding the reduction in accuracy required, the Atlas guidance system is as difficult a manufacturing task as any yet attempted. Some notes on inertial systems are provided elsewhere in this issue. Hundreds of parts have tolerances of the order of millionths of an inch, and a typical indication of the scale of effort required is provided by a contract worth nearly half a million pounds awarded to the Gruen Watch Company for gyro-system test equipment.

Five months ago Convair Astronautics broke ground on a £15m plant north-east of San Diego for research, development and production of the basic SM-65A. Convair paid just over half the cost of this facility; it will have one million square feet of floor space and will be in full operation next October with a staff of 6,600. Construction of static-test and launching facilities at Patrick A.F.B. started one year ago; they include a blockhouse with a roof 25ft thick. At Edwards A.F.B. £540,000 has been spent on a static firing stand complete with fuel systems, tanks, controls and North American B-2C motors. There are also two other Atlas test bases, both operated in the San Diego area by Convair personnel. One of these is in Sycamore Canyon, not far from the Atlas factory; this base is near completion and will be used for checking out systems, including the firing of the motors. The other facility is at Point Loma and will be used for component testing.

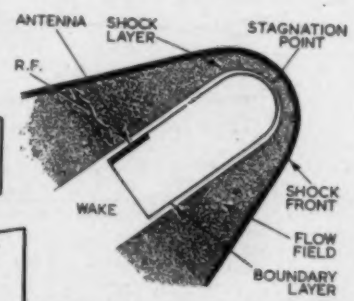
Meanwhile, Convair have nearly finished the assembly of the prototype and this vehicle is scheduled for test firing at Patrick some time next year. The company's very extensive test equipment required by the firing trials includes continuous-wave tracking equipment. It was recently announced that the second Convair control facility was being

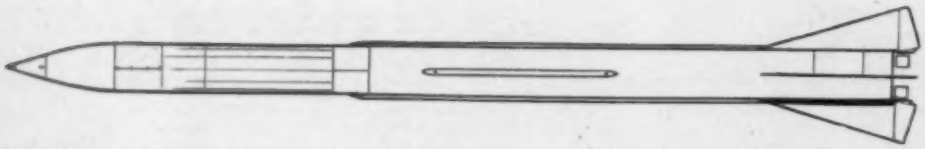
Atlas (* provisional drawing). SSM with two 100,000 lb-thrust liquid-propellant boost motors and one 135,000 lb-thrust liquid-propellant sustainer. Overall length (or height), about 100ft; weight, about 90,000 lb; burn-out speed, about M=15; trajectory peak, about 800 miles; max. range, 5,000 miles.



Note: Atlas, like Corporal (p. 904) and Redstone (p. 906), is launched from a vertical position.

The small diagram on the right illustrates hypersonic flow round a non-pointed nose, characteristic of all ICBM warheads.





Corporal. SSM with liquid-propellant sustainer; no boost motor. Length (height), 45ft; fin span, 7ft; body diameter, 30in; weight, 12,000 lb; burn-out speed, M=3.5; max. range, about 50 miles.

Guided Missiles 1956 . . .

(United States of America—continued)

established at San Salvador A.F.B. As for the missile itself, it has been said that component reliability is proving a difficult problem in view of the environmental conditions anticipated. Nevertheless, during congressional testimony last May it was stated that "the last technical barrier" had been overcome and that all that was left was "a systems engineering job of great magnitude."

Corporal. This powerful and valuable weapon has been described as "a crash programme that has paid off." Today it is in wide service with the U.S. Army as a standard heavy support missile for striking major targets deep in the rear of an enemy army from 20 to 50 miles from the firing point.

Originally Corporal was not a weapon at all. The basic development of rocket research vehicles at the Jet Propulsion Laboratory of the California Institute of Technology was begun in 1944, under the sponsorship of Army Ordnance contracts. After extensive experimentation with Private, Private 1st Class and WAC Corporal (the second stage of project Bumper), J.P.L. evolved a larger vehicle designated Corporal E. The characteristics of this were such that in 1952 it was adopted as "a back-stop to another Army programme" and a complete weapons system was based on it. The task involved was a formidable one in the state of the art then prevailing, but it was undertaken with extreme urgency. By September of the same year the system was sufficiently advanced for production orders to be placed, and a very wide spread of sub-contractors was marshalled.

Two prime contractors were chosen: the Firestone Tire and Rubber Company for the airframe and Gilfillan for guidance. The chief sub-contractors were Motorola (for guidance) and Ryan, who have built all the 20,000 lb-thrust Corporal motors to J.P.L. design since 1951. J.P.L. remained basic system-managers and undertook the bulk of the development of the ground and support equipment.

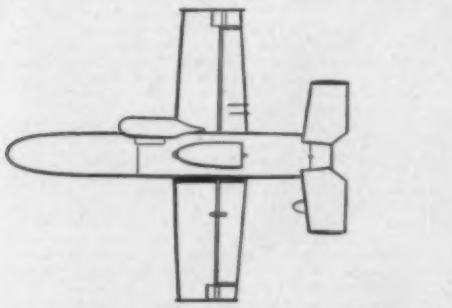
The basic Corporal is a straightforward, vertical-launched, wingless missile. The warhead—of which various types, nuclear or otherwise, are available to suit the requirements of each mission—is built integrally with the nose structure. The latter is of ogive form and is an aluminium-alloy spinning in current Corporals, although the construction is now being changed to a phenolic moulding. Immediately to the rear of the warhead is the guidance package, and behind that is a polygonal section containing high-pressure air tanks charged before launching to 2,350 lb/sq in. This pressure is metered and used to feed the propellants to the motor and operate the various valves. Fuel (mono-ethyl aniline) and oxidant (red fuming nitric acid) are contained in tanks occupying the bulk of the missile body, and fed to the motor through external faired pipes. The motor has a single, regeneratively-cooled chamber. Control is effected by aerodynamic rudders on the four delta fins (these are much smaller than the trapezoidal surfaces of Corporal E) and vanes within the propulsive jet for use during the first few seconds of flight. These vanes were originally of carbon but in recent Corporals are of a special plastic material.

A Corporal battalion is completely mobile. Its total personnel strength is 249, divided into an administrative/H.Q. battery and a technical, operations and launching battery—a new arrangement which is proving to be most flexible in practice. The operator battery has 94 men; 27 in the launching crew, eight electronic assemblers, 39 mechanical assemblers and 20 in the fire-control crew. When a missile is required for use it is drawn from store, assembled, loaded on to its vehicle and fuelled. The vehicle is particularly ingenious since it comprises a self-propelled transporter, launcher, servicing platform and bulldozer on one set of wheels. This vehicle and the whole supporting column has full cross-country performance.

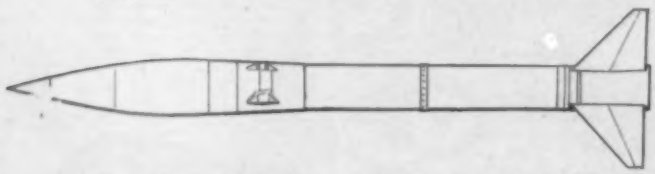
Several hours must elapse between arrival at the desired launching site and ability to fire. While the support vehicles take up their positions and the various cable links are made, the firing site itself is levelled by the bulldozer. The erector beam to which the Corporal is clamped is hydraulically raised until the missile is standing vertically on a four-armed launching cradle, with the rocket motor centred over a conical flame deflector. The erector beam is then unclamped and the missile is left standing in the centre of a clear area, stable on its cradle in winds up to 55 m.p.h. Servicing is effected from a platform at the end of a double-hinged arm on the transporter vehicle, while multiple checks are performed and the air tanks are filled. Sequential "go/no-go" tests are also carried out on the seven supporting vehicles, which comprise an AN/MPQ-25 tracking radar, AN/MSA-6 computor, AN/MRQ-7 Doppler radio, three generators and the battery-control station.

The final count-down during firing reaches "zero" at full thrust and then continues with the alphabet. Launching is truly vertical and the subsequent flight is of an unusual guided-ballistic nature, in that control is exercised even after burn-out. Throughout, the flight path is compared with a known standard, computed for the range required and corrected as necessary. At the required velocity—usually about one minute from firing—a radio command shuts off the motor; at the same time a range-correction signal is fed in and the warhead is armed. Velocity at burn-out is approximately Mach 3. When firing against targets at about 50 miles range, the total time of flight is approximately 225 sec and the peak of trajectory about 270,000ft. Operationally the Corporal is truly all-weather, although optical vision makes firing and guidance somewhat easier.

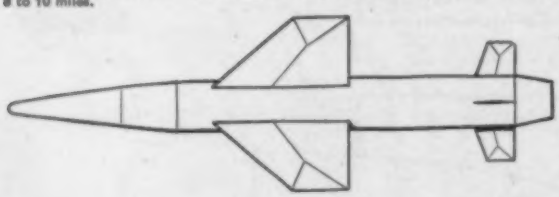
Bulk production of Corporal began late in 1953 and the complete weapon system reached the Army in "sizeable quantities" the following year. Production was stepped up in August 1954 by the opening of a new factory in Los Angeles, under Firestone management. The first Corporal battalion became operational during 1954, and early in 1955 the 259th Field Artillery Missile Battalion came to Germany, fully trained and equipped. During the 12 months which ended last June eight battalions became operational and six of these have for some time been serving in Europe. The Army/Navy designation of Corporal is SSM-A-17 and the Army service designation is M4E-1.



Dart. SSM with solid-propellant motor. Length, about 6ft; span, about 5ft 3in; body diameter, about 10in; weight, about 300 lb; flight speed, subsonic; range, up to 3 miles.



Honest John. SSM with solid-propellant motor. Overall length, 27ft 3in; fin span, 8ft; diameter, 30in at warhead, 23in along body; weight, 5,980 lb with 1,500 lb warhead; burn-out speed, M=1.5; max. operational range, 30,000 yd.



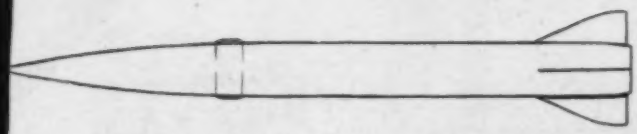
Lacrosse. SSM with solid-propellant motor. Overall length, about 9ft; span, about 3ft 9in; weight, about 500 lb; speed at burn-out, about M=0.8; operational range, 8 to 10 miles.

Corporal Mk 2. Also designated Corporal F, this missile differs in several respects, although it looks substantially similar and uses most of the existing Corporal ground equipment. All the Corporal battalions in Europe are currently being rotated back to the U.S.A. to re-equip with the improved weapon.

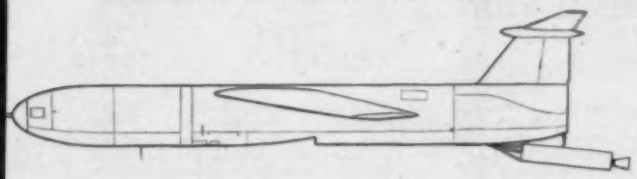
In March last year it was announced that Corporal Mk 2 would be adopted by the British Army and that units to fire it would be formed during 1956. In February of this year it was announced that a large number had been ordered as a standard surface-to-surface missile of the Royal Artillery (to replace a British weapon cancelled in 1953). It is understood that R.A. units are at present training on the S. Uist range in the Outer Hebrides.

Dart. Developed to Army Ordnance contract by the Aerophysics Development Corpn., a subsidiary of Studebaker-Packard, Dart is going into production at Utica-Bend, a plant recently acquired in Utica, Mich. Aerophysics are based in California, having recently moved from Santa Monica to Santa Barbara.

Dart is for use by ground troops against tanks or bunkers. It has cruciform wings/controls, and is steered by wire command guidance. Propulsion is by solid rocket. Tests against various targets early this year were successful, and the final weapon system is to be operational in



Little John XM47. SSM, ballistic, spin-stabilized missile propelled by short-duration solid sustainer. Length, about 12ft; fin span, about 30in; body diameter, 318mm (about 12½in); weight, about 900 lb; range, 18,000yd.



Matador TM-61B. SSM with 4,600 lb-thrust J33 turbojet; launched with solid-propellant boost motor. Overall length, about 45ft 10in; wing span, 28ft 9½in; body diameter, 54in; weight, about 13,800 lb (TM-61A is 12,000); cruising speed, M=0.9; operational range, 600 miles.

18 months' time, although an interim system is virtually ready now.

Dart's Army designation is SSM-A-23. It is designed particularly for anti-A.F.V. use and has a shaped charge in the nose. For field use it is fired and guided from a simple launcher on an M59 personnel carrier. Guidance is effected by a unique optical-tracking system by H. A. Wagner Co., the rocket motor (by Grand Central Aircraft's rocket division) being smokeless, and sodium flares being fixed to the Dart to assist in tracking. During a recent demonstration a Dart went through the edge of the bull on an 8ft-square moving target at 2,100yd.

Honest John. Strictly speaking not a guided weapon at all, this awe-inspiring missile is nevertheless worthy of inclusion in that it fulfils a typical SSM function. It is a standard 762mm (30in) artillery rocket used for tactical purposes.

It was in May 1950 that Army Ordnance prepared the first study. Douglas Aircraft worked rapidly on this specification and submitted detailed proposals for a production missile. They were accepted, and the first Honest John was fired at White Sands in August 1951. Douglas started bulk production at Santa Monica in January 1953. Army units started conversion to the new weapon early in 1954 and it is now widely used in several theatres.

Honest John is virtually a much-scaled-up Bazooka. For use, a missile body is drawn from store, taken to the launching site and fitted with a suitable warhead—nuclear or otherwise. It is then mounted on the single launching rail on a self-propelled launching vehicle (developed by Rock Island, Ill, Arsenal), and the stabilizing tail is added. If not required for immediate use the propulsive charge and warhead are kept at the correct temperature by a G.E. electric blanket.

No connections to the missile are necessary apart from the single firing cable, and no tests are necessary. Aiming and fire-control are virtually the same as the procedures used in normal artillery. The launching vehicle is steered to the correct azimuth and the rail is elevated to the required angle for the range.

Acceleration at firing is very high. Propulsion is by a single 2,000-lb (weight) cast charge made by the Hercules Powder Co. There is no guidance system, but the missile is spin-stabilized by four small M-7 rockets firing tangentially around the rear of the warhead. These rockets give rise to a white cloud which surrounds the missile during firing; the spin which they engender is maintained by a slight canting of the four stabilizing fins.

Well over 600 Honest Johns have been fired at White Sands alone, and many thousands have now been made by Douglas and by Emerson Electric, for some years a second-source supplier. Introduction to Army service has been simple, in view of the few new procedures involved. The missile has proved to have better battlefield manœuvrability than heavy artillery and to "pack the heaviest punch." Range with the 1,500-lb warhead (the most usual size) is 30,000 yd. Trajectory data are: 11-deg elevation, peak altitude of 900ft in 9 sec and 10,000 yd strike in 16.5 sec; 50-deg elevation, peak of 30,000ft in 41 sec and strike at 30,000 yd in 87 sec.

Intensive field trials have been held in Japan and in the Grafenwoehr area of Germany, the 7th Field Artillery being a major European user of the missile. Studies have been made for launching from large helicopters, and the Marine Corps are also to use the missile. It is being supplanted by Little John (q.v.).

Jupiter. At the inception of this IRBM programme it was envisaged that it would be a joint Army/Navy undertaking. It was soon appreciated that one missile could not suit both Services, and that a compromise would suit neither. Originally the project was for a 1,500-mile missile to back-up Thor, and it was accorded high priority. Prime responsibility was vested in Redstone Arsenal, and the programme used all the resources of this arsenal and of many sections of industry.

Early in 1956 it was reported that the Navy were to work out an IRBM for themselves, and the weapon is referred to below, as "Naval IRBM." Meanwhile the Army Ordnance weapon has crystallized as Jupiter C, a successor to Jupiter A (i.e., Redstone). Chrysler have system responsibility, and will probably handle production. The Jupiter C will, like its predecessor, be a slim single-stage missile with a liquid-propellant motor. Rumour has it that much of the structure will be of magnesium, although this would not stand up well to kinetic heating. Ford Instrument Co. are again responsible for inertial guidance. Gen. Medaris recently stated, "we have very great hopes of this weapon, and development is maintaining schedule."

Lacrosse. This programme for a close-support missile was originated by the U.S. Marine Corps in 1947, and in August 1953 the Corps expressed pleasure at its progress. Development was handled by the Cornell Laboratory, who had systems responsibility and conducted trials at White Sands. Late in 1954 production bids were called, and the first contract—for from 20 to 100 airframes—was placed with Martin. Launchers and guidance units were also bought, for truck mounting.

This contract was a joint U.S.M.C./Army purchase and the programme is now directed by Army Ordnance. Originally the mission was similar to that of Honest John, but there are now two Lacrosse variants, one of which has an all-weather guidance system which does not require that the target should be visible. In the original contract the Marines sought £214,000 for the control system and £135,000 for the missile. Five months ago Marine Corps personnel began to visit Redstone, Ft. Sill and Martin for training. Lacrosse should be operational next year.

Little John. In May 1955 the Army stated that "progress has been made on a greatly improved tactical support missile which has highly significant logistic and operations advantages over the currently available model. Work is continuing on a longer-range model which will allow maximum exploitation of available destructive effect in new and improved warheads."

Little John, a refined tactical missile evolved from the bulkier Honest John, has for two years been made by Redstone Arsenal. Although it can match its parent's performance and can have a nuclear head, it is smaller and neater and can be carried in an ordinary truck. Supply to forward troops can be by helicopter.

Matador. Basic investigation into the design of a pilotless tactical bomber for the U.S. Air Force was begun by Glenn L. Martin (now the Martin Company) in 1947. The design was worked out in detail the following year and took the form of a small mid-wing machine of almost perfect streamline form. Power was provided by an Allison J33 turbojet fed from a ventral intake behind the centre-fuselage tanks. The first launching was on January 20, 1949.

During the ensuing three years the design was appreciably altered. Fuselage length grew in order to increase the fuel capacity, and the wing was shifted to the high position. The empennage was completely redesigned, the height of the vertical tail being increased, and a bullet-fairing was added at the junction with the tailplane, which was modified to have dihedral. The machine was designated B-61 Matador and, after acceptance by the Air Force as a basis for a useful weapon, a complete system was evolved around it.

The missile itself was sub-divided into sections—centre fuselage and fuel cells, tailplane, fin, rear fuselage shell, port and starboard wings, nose cone and engine can—each of which was arranged for shipment in a specially designed crate. The design was so prepared that only one in each batch of Matadors needed to be assembled in the Martin factory in Baltimore, the bulk of the components, all completely interchangeable, being crated for shipment to an Air Force base for subsequent field assembly by enlisted men. In addition to the seven crates, separate boxes were designed for the tail cone, electronic guidance shelf, warhead (in either one or two sections) and RATO bottle. The weapons system was completed by a zero-length launcher, ground-support vehicles, base area, automatic go/no-go sequential test equipment, packaged spares for long storage, and other items such as depot and housing facilities.

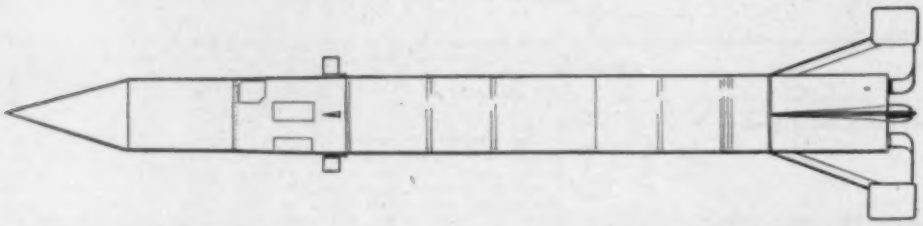
Martin's airframe design is a model of how a requirement can be economically met. The Matador's structure is largely built up from bonded metal honeycomb, contoured by one pass of a band-saw, and used as a filling between stressed skins. The powerplant was also completely re-engineered from the basic engine used in piloted aircraft, in order to provide a cheap and reliable turbojet suitable for the missile. During development there were several off-shoots from the basic design. In 1953 a recoverable drone system was tested and such aircraft, then designated QB-61, were used as targets for Nike and other anti-aircraft weapons. Early the same year the Air Force voted £230,000 for a project to modify six Matadors to carry calibration equipment for instrumentation intended for use in connection with Falcon (q.v.).

By late 1954 Matador squadrons were deployed in Germany, the missile itself then being designated TM-61. The first unit was actually "activated" as early as 1951 but it took three years for the system to become operational with Tactical Air Command. Each squadron has 53 officers and 543 airmen. The vehicle is assembled in jigs which form an integral part of the transport vehicle, and the warhead and RATO bottle are added on the firing pad. Complete assembly and check-out may take from one to five hours, and the missile can be held at readiness for a fair period, although there is a danger of electronic burn-out.

The zero-length launcher has its own hydraulic, electric and fuel systems for supplying the missile. Launching is effected by running up to 100-per-cent power against a hold-back bolt, which is finally sheared by the firing of the RATO bottle. Guidance is effected from a missile-control and target-selection van, which also governs the pre-launching checks. Crews are trained on T-33s equipped with a Matador-type brain, and a simulator (made by Link) is also used to generate TM-61 signals. Each squadron requires a large number of 60 kW generators, indicative of the tremendous electrical consumption. Each launcher is linked to the squadron operations centre by a U.H.F./F.M. network.

TM-61B. Production is now centred on this appreciably more effective development. The original TM-61A was limited not by fuel but by the maximum range of the guidance system. In the new Matador a completely revised and self-contained guidance system is fitted, the basic inertial system having been test-flown in February of this year in a modified TM-61A. Responsibility for guidance has been shared by A.C. Electronics (ex-Spark Plug) Division of General Motors and by Goodyear who have developed the Atran system. Severing the radar communications between the missile and the launching site has greatly increased the distance to which accuracy can be maintained. Accordingly, the tankage has been substantially increased and the TM-61B has a longer and far more capacious fuselage in consequence.

Like the TM-61A, the new missile can have a nuclear warhead and can reach supersonic speed in its final dive on to its target. The first



Redstone (Jupiter A). SSM with single liquid-propellant motor of 65,000 lb thrust. Low-speed fins and controls at rear, high-speed controls at rear of forward section. Length, 69ft 6in; fin span, 14ft 6in; body diameter, about 5ft 11in; weight, about 40,000 lb; ultimate range, more than 200 miles; burn-out speed, M—5.

Guided Missiles 1956 . . .

(*United States of America—continued*)

test-firing programme of the revised missile was successfully completed at Holloman in March. Production orders were placed earlier this year at a unit cost which is unlikely to exceed the average figure of £30,500 of the earlier version. Interest is also being shown by the U.S. Navy and Marine Corps.

Naval IRBM. After some months of frustration, the Navy came to the conclusion at the beginning of this year that, if they were ever to operate a shipboard IRBM, it would have to be specially tailored for them. They accordingly broke away from the joint programme based at Redstone (see Jupiter) and initiated a design for a different form of missile—which may, in the event, prove to be operationally superior.

In particular, the Navy wanted to use a solid propellant, which should be much easier than liquids to handle below decks. They were also adamant against the Army's concept of a long, slender missile, which could never have got below decks at all; the new IRBM will be short and squat. By April the programme was "well under way" and it was stated that in the 1958 fiscal year money would be sought to complete the capital ship *Kentucky* for IRBM use. Rear-Admiral John E. Clark, director of guided missiles in the office of the Chief of Naval Operations, recently said, "by the summer of 1957 we will be reasonably sure of the form that our ballistic missile will take and we are already designing ships to carry it."

Navaho. Although a cruise-type missile, with air-breathing engines and an aircraft configuration, Navaho flies higher and faster than anything else apart from a ballistic missile. It also has global range.

Development began around 1950, when the U.S.A.F. asked North American Aviation to study prospects for a ramjet-powered long-range pilotless bomber. This materialized as the B-64, and a truly tremendous programme of research was started. The company, as prime contractor, let out contracts for propulsion to Curtiss-Wright, but retained most of the work themselves. They are anxious to point out that they were not enamoured of the prospect of entering many non-aeronautical fields; they were forced to do so owing to the inability of specialist firms to deliver the goods, or learn the special skills required.

Chief of the N.A.A. divisions involved are Aero-Physics, Autonetics and Rocketdyne (these were originally known as MACE—Missile and Control Equipment). Autonetics in particular have had much to do with Navaho, which is now redesignated SM-64. The division employs over 8,000, and its largest section is "guidance," where remarkable research has resulted in some of the world's finest celestial and inertial developments. Aerodynamic investigation was partly farmed out to such centres at the JPL at Caltech.

Flight trials started in January 1954, when an X-10 vehicle—similar in important respects to SM-64 but powered by a pair of Westinghouse J40 turbojets—flew at Edwards A.F.B. Several versions of the SM-64 were envisaged, and the use of turbojet test vehicles allowed many formidable problems to be solved in relatively easy stages. More advanced flight testing began early this year and 25 revised G-26M vehicles had flown by June; 20, with landing gear retracting into the body, had been recovered. Several had flown right down the Missile Test Center range and back, to be landed at Patrick A.F.B.

In New Jersey, the great Wright RJ47 ramjet, 48in in diameter and capable of delivering between 30,000 and 40,000 lb thrust, was evaluated under conditions appropriate to Mach 3 at 90,000ft. Contracts were let to T. R. Finn and Avco for the nozzle liner and housing, and photographs of these units have recently been published in America. As far as is known the RJ47 is the most powerful air-breathing engine yet made.

No illustrations of the SM-64 configuration may be published, but one may expect to see a very long cylindrical body with stubby wings carrying the powerplants at their tips. The G-26M vehicle has a vee tail. Take-off thrust is provided by a triple-barrel N.A.A. liquid-propellant rocket motor, with a thrust of more than 100,000 lb. Walter Kidde make the accessory powerplant. A typical skin temperature for the airframe in cruising flight is 300 deg F. Much of the primary structure is made from large sections of fairly thick 24S-T skin, etched away by the company's chemical-milling process to leave a thinner skin with integral inserts. Double skins are then placed back-to-back and filled with a honeycomb which is previously Kellered to profile while stabilized with epoxy resin. Such a structure has been found to be cheap, accurate and efficient.

Earlier this year, Donald Quarles, Secretary of the Air Force, said of air-breathing missiles (meaning SM-64), "range and load-carrying ability will be at least equal to the ICBM, and some of them will be so difficult to intercept that I would expect their ability to get through to be comparable—though not equal—to the ballistic missile." It is known that Navaho can take evasive action. Original design cruise was Mach 2.5 at 65,000ft, which has already been far exceeded. Current figures are Mach 3 at 75,000ft and it is later hoped to attain 90,000ft. Fully representative SM-64s are now on test from Patrick, and research and development were to be continued by a £23.3m appropriation in October. It was stated in June that the programme "could have used additional funds wisely." Navaho may join the Air Force in 1958.

Redstone. Although recently renamed Jupiter A, this impressive ballistic missile remains popularly known by its original name. It was developed, not by private industry, but by the "V.2 group" of ex-Peenemunde engineers under Dr. Wernher v. Braun, who for many years have worked at the Army Missile Development Center, Redstone Arsenal.

Chrysler Corporation received the production contract, in January 1953. The Navy-financed plant in Detroit (originally to have made J48 turbojets) was suitably tooled and, despite some delays, bulk delivery began early this year. First firing was in May 1953, and Army Ordnance teams began regular firing at Patrick early the following year.

Comparison with the classic A-4 (V.2) shows the greater efficiency of the new weapon. The body is a cylinder wrapped from aluminium sheet, and housing the liquid-oxygen and fuel tanks for the single-chamber N.A.A. Rocketdyne motor. The warhead can be of the hydrogen type, and an outstandingly good inertial guidance system has been evolved by Sperry Rand's Ford Instrument Co.

Last month Gen. John B. Medaris, commander of the Ballistic Missile Agency, said, "security status precludes disclosure of more than ten per cent of the achievements. We have challenged the Redstone system with a wide variety of objectives above and beyond those already achieved by the missile as a single weapon system. Every such challenge has been met in superlative fashion, successfully and on time." There is no doubt that the production Jupiter A, which differs considerably from the original Fort Bliss concept, is a fine weapon. In May the 217th Field Artillery Missile Battalion (Redstone) started full training. It has been found that the advanced design of their weapon requires fewer highly trained specialists than does the short-range Corporal.

Redstone is at present being issued to a number of battalions. Each platoon handles one missile at a time and has a column of nine vehicles. The Redstone itself is divided into its two halves: the rear, containing tanks, motor and low-speed stabilizing and control surfaces, and the front, housing warhead, inertial guidance and the three small Mach-5 surfaces which effect trajectory corrections. A 25-ton crane lifts the halves to a horizontal position for joining and check-out. The complete missile is then positioned upright on its firing base, carefully aligned with its final target 200 or more miles away. Alcohol, liquid oxygen and peroxide (for the turbopump) are put in, in that order. The bulk of the column then depart to prepare the next firing site; fire-control stays hooked-up until the five-minute signal, and the liquid-oxygen tanks are continuously topped-up (against loss by evaporation) until the final count-down begins.

Regulus. In practice, this aircraft-type vehicle is unlikely to be used as an offensive weapon. Nevertheless, it is cheap, reliable and is giving good service for training and many other purposes.

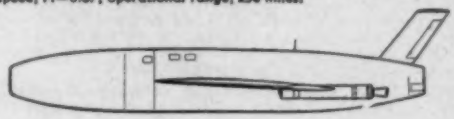
It is a typical Chance Vought design, and was begun by that company (then a branch of United Aircraft) in 1947, to a BuAer contract. The A/N designation was XSSM-N-8. The basic airframe is simple in the extreme. The fuselage is a conventional stressed-skin structure full of air duct and fuel, and carrying an Allison J33-A-14 or 18A at the rear. Aerodynamic surfaces are generally precision-cast in magnesium alloy; the wings fold roughly at the mid-point of each semi-span and the folding portions are single magnesium panels each weighing 162 lb finished. Except for the wing, much of the structure is made from the company's Metalite light-alloy/balsa sandwich. There is no horizontal tail, the elevators being on the wings, inboard of the ailerons.

All development and production has been done at Dallas, Tex. The first test vehicle flew in 1950, at Edwards A.F.B., and some hundreds have since been fired in several programmes of trials. A considerable proportion of Regulus production has been of a re-usable version with a retractable undercarriage and a braking parachute. It has been found that 100 hours of testing would necessitate the consumption of 200 non-recoverable Regulus, whereas only 30 re-usable vehicles have been needed in practice. At least one has flown 30 times.

Production for the Navy started in March 1953, by which time £14.3m had been spent on development. Most of the SSM-N-8s so far built have had drone-type command guidance, but a revised longer-range guidance system is used on examples built as tactical missiles. A Sperry autopilot is standard. Launching is normally from a simple beam, with thrust from twin Aerojet solid boosters. Guidance signals for launching are passed through 100ft of "umbilical cord" which is severed at the fuselage as the missile departs.

A number of Regulus have flown missions longer than the quoted 200-mile range, and they have also demonstrated their ability to carry a nuclear warhead (such a warhead has not actually been carried, as far as is known) and to dive on to a target at supersonic speed. Test firings

Regulus I. SSM with 4,600 lb-thrust J33 turbojet; launched by two solid-propellant boost motors. Length, 32ft 6in; span, 21ft; body diameter, 54in; weight, 14,520 lb; cruise speed, M—0.87; operational range, 250 miles.



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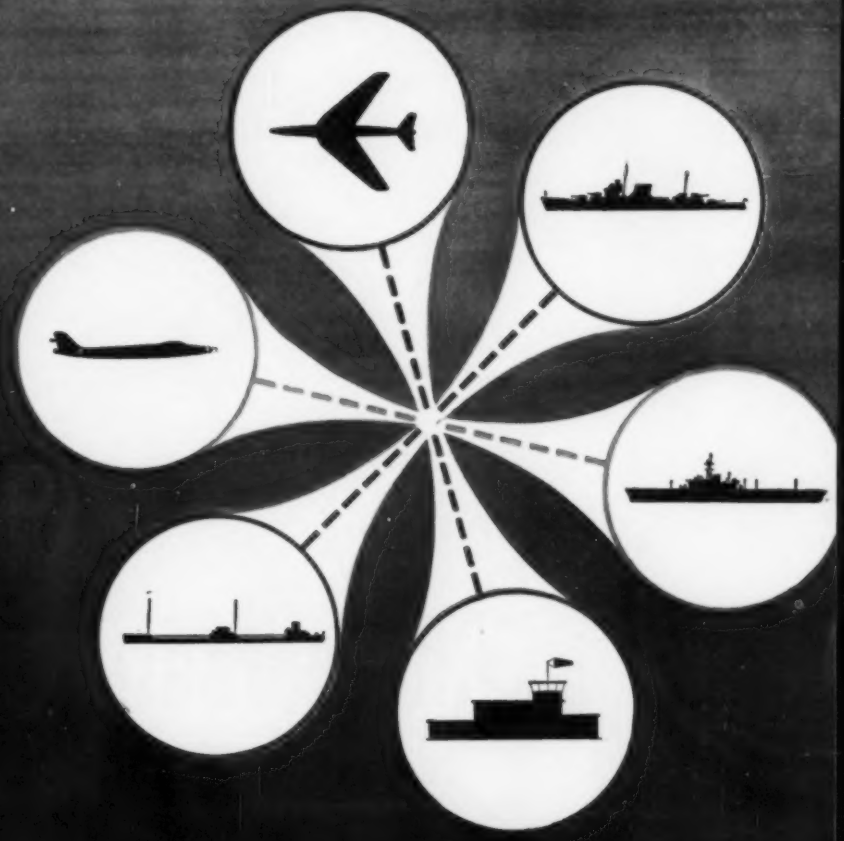

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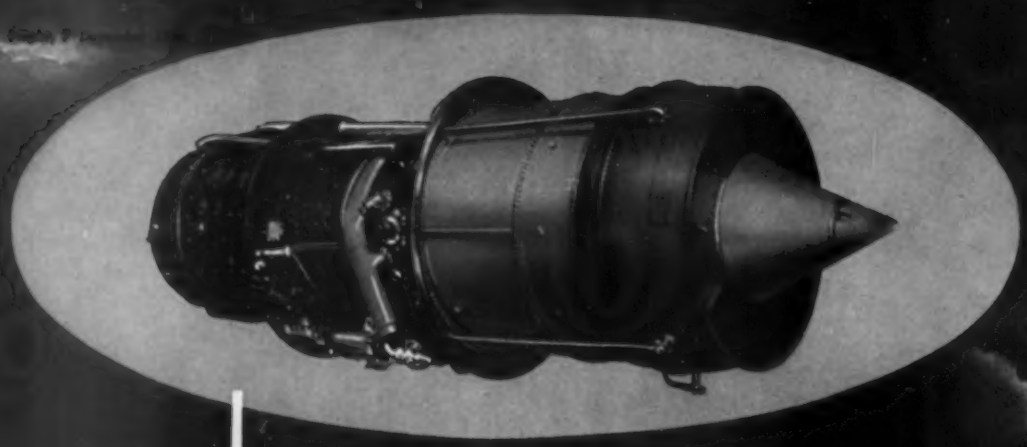

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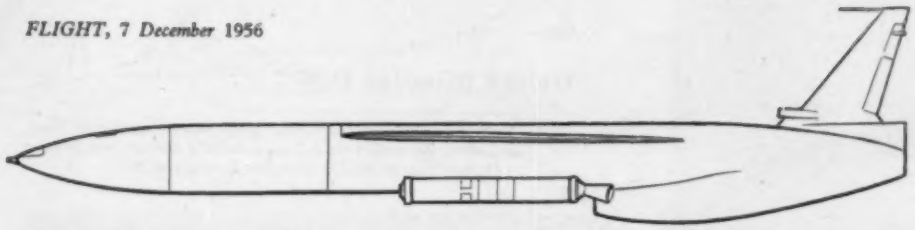


Snark. SSM with 11,000 lb-thrust J57 turbojet; launched by two 33,000 lb-thrust solid-propellant boost motors. Overall length, 74ft; span, 42ft; height, 15ft; body depth, 67in; weight, 35,000-38,000 lb; cruise speed, M=0.9; range, at least 4,000 miles.

Guided Missiles 1956 . . .

(United States of America—continued)

were carried out from Point Mugu, Cal, and from the U.S.S. *Norton Sound* and the carrier *Princeton*. The large submarine *Tunny* has for over a year had a Regulus hangar and launching gear, and *Barbero* recently joined the Fleet with similar equipment. In June last there were four carriers, four cruisers and two submarines equipped for Regulus SSM operations. A recent improvement was the development of a neat steel-tube dolly with which Regulus can be catapulted from a carrier; previously it had been necessary to use a large wheeled platform with RATO bottles.

Snark. This unique long-range, aircraft-type, cruise missile was developed to the high-subsonic formula in 1947. At that time Northrop Aircraft were well advanced in the design of tailless machines and this was the configuration adopted.

Requirements of the original Air Force specification were a range of 4,000 miles at 600 m.p.h., with suitability for mass production at a reasonable price. Extensive development was conducted with various test vehicles (P-61s were used for guidance trials) and it was from this work that the company became interested in sleds, which were used for many early Snark tests. By 1949 a scale model was flying, with a span of 32ft and an Allison J33 for power.

The real Snark (originally B-62 and now SM-62) is much larger. Of particular interest is the wing, the 45-deg sweep of which was exceptional at the time of design. The outer panels have increased leading-edge chord, and the trailing edge carries elevons. Much of the wing is skinned with very large cast magnesium-alloy panels; sandwich is used in the secondary structure and light members are stabilized by foamed-in-place fillers.

All the systems are housed in the capacious 74ft fuselage. At the front is the warhead, which can be of the thermo-nuclear type. Next comes the advanced, and reliable, Mk I celestial guidance system, which automatically tracks stars. All the central portions are filled with fuel, and at the rear is a ventral duct housing a Pratt and Whitney J57 turbojet. Earlier Snarks had an Allison J71 which, although lighter, had about 20-per-cent higher fuel consumption; the change to the Pratt and Whitney—the most expensive missile engine at present in use—allowed the guidance system (which weighs twice the original 500-lb estimate) to overflow into bays originally occupied by tankage, without any reduction in range.

Manufacture of complete Snarks has gone ahead at Hawthorne since 1951. Curiously, 68 per cent of the work (i.e., £50.3m) has been financed by production contracts, although there has been no production as such. Since the end of 1954 SM-62s have been flown to Patrick inside C-124 transports, each of which can accept a complete Snark in dismantled condition. Flight trials have gone well in recent years, although 13 flew into the Atlantic prematurely as a result of guidance malfunction. Several have flown 2,000 miles down the range and back, to be landed by skids and a tail parachute (this recalls the round-trip "autobomber" version of Snark projected in 1953).

Launching is effected from a zero-length rail. Once the big boost motors are off, the missile climbs to about 60,000ft at constant i.a.s. and cruises at about Mach 0.9 at the high angle of attack characteristic of tailless machines. An evasive path can be programmed before the final dive, all control being exercised through an autopilot. The latter is continuously fed with intelligence from the star-tracking head, produced by Northrop's Anaheim Division. In its construction there is a great assortment of advanced optics, together with large castings which are machined and then hand-lapped to ± 1 sec of arc.

Although the cost of the SM-62 is only about five per cent of that of a B-52—so it is stated—it is unlikely to be built in quantity. In February there was a chance of an order for 50 or more Snarks per month, but the SM-64 and SM-65A now seem to have developed too rapidly.

Thor. At the end of 1955 the Air Force were given control of all new SSM projects in the 1,000/1,500-mile range class—in addition to having sole responsibility for ICBMs. An Air Force IRBM was authorized as Weapon System 315A, and this programme has since had first priority.

Full systems responsibility was assigned last January to Douglas, Santa Monica. Named Thor, the new missile is a single-stage weapon, with all major components derived from existing parts of ICBM systems. Development has been extremely rapid, reflecting the ability and experience of the design teams. Propulsion is by a liquid-oxygen motor under development by N.A.A. Rocketdyne Division; guidance is by A.C. Electronics Division, with help from Bell Telephone Laboratories and Remington Rand (Univac); the nose cone is a G.E. responsibility; and A.M.F. are developing auxiliary propulsion and accessory units. The first Thor arrived at Patrick last month and many firings should be carried out next year.

Titan. During 1955 the Air Force considered that the ICBM programme was so vital that it would be worthwhile starting a second programme to back-stop the first (Atlas). The second ICBM is Weapon System 107 and in October last year The Martin Company were named systems manager.

WS-107, or Titan as it is named, is a weapon which, although it uses essentially similar components to those already developed for Atlas, is of quite different configuration. In this way two approaches to the problem can be evaluated for an expenditure only 10 per cent greater than that required by Atlas alone. The two missiles are identical in all major performance characteristics.

Unlike Atlas, Titan is a two-stage missile. Although Martin engineers are very interested in novel lateral-staging configurations, Titan will have a conventional one-above-the-other layout. Aerojet-General are making the first-stage motor, with R.M.I. a major subcontractor for chambers. The guidance system has been awarded to G.E., who are also responsible for the nose cone. Martin themselves are building a half-million square foot plant for Titan, on a 5,000-acre site south of Denver, Colorado. Ground was broken in February and the building was finished last month; it cost the company over £7m and will employ over 5,000 on WS-107 next year.

Triton. Probably the ultimate development of Project Bumblebee, Triton is a large Navy BuOrd missile originally evolved by JHU/APL. Designed for "just under Mach 2.5," the missile is certain to be similar to a scaled-up Terrier (q.v.). Overall length is about 45ft, body diameter 57in and launching weight 19,000 to 20,000 lb. One report avers that Triton will be manufactured by Boeing.

FRANCE

AIR-TO-AIR

Matra AA.20. Powered by a single-barrel 2,760-lb S.E.P.R. motor running on RFNA and petrol, the AA.20 is a Mach-1.5 weapon with a length of no less than 15ft. Effective air-to-air range is to be not less than 10 miles. It is about to pass into pre-production, for ultimate issue to Mystère IV squadrons.

Matra M.04. Although extensively test-fired from various aircraft (such as the Halifax and Grognard) at Colomb-Bechar, this vehicle is really a two-thirds scale model of a larger weapon. Development began in 1952 and the Société Matra have collaborated with Sud-Est Aviation in perfecting it. Later variants will be ground-launched, with a longer burning-time than the 14 sec of the present S.E.P.R. motor. A surface-launched A.A. weapon may result.

Matra R-051. This is almost unique in being a fighter-launched missile with an aircraft-type (one set of wings) configuration. It is claimed to have exceptional range, and it has been adopted as a standard piece of ordnance for the all-weather Vautour. Launching is carried out from a zero-length shoe. It has a two-stage solid-propellant motor and is 9ft 10in in length; the weight is 353 lb and the burn-out speed 1,100 m.p.h. Flight testing has been carried out with several machines, including N.F. Meteors.

Nord 5103. Developed originally by l'Arsenal, which became S.F.E.C.M.A.S. before merging with the Nord aircraft group, the 5103 is an air-to-air missile with a swept-wing cruciform—a very unusual design. The drawing shows the missile without boost, although it is alleged—surprisingly—that a boost is used.

Both boost and sustainer are solid-propellant rockets, and guidance is effected initially by beam riding. A proximity fuse is fitted and the controls appear to be hinged to the wing cruciform. Flight tests have been conducted from Meteor night fighters.

SURFACE-TO-AIR

Parca. Bearing a name formed from the initial letters of its designated function—a practice common with French missiles—this close-knit weapon is nearing the production stage. It has been developed by the D.E.F.A. (Directions des Etudes et Fabrication d'Armement).

As the drawing shows, it is a canard, with a large proximity-fused warhead, and wrap-round boosts. When the latter are jettisoned the missile does not look untidy. It has been tested at Colomb-Bechar and is stated to have destroyed targets flying "at the speed of sound at 10,000 m (32,800ft)."

S.N.E.C.M.A. Largest aero-engine firm on the Continent, this company are developing two missiles for the Aéronavale. They are known as MARUCA and MASALCA, which indicate that they are both anti-aircraft weapons.

S.E.4100. Developed by Sud-Est Aviation, a major nationalized aircraft firm, the 4100 is a fairly slow SAM, reminiscent of German work in 1945. It is, nevertheless, a weapon with great punch for its size and cost. Composite construction is used, and the sustainer uses nitric acid and petrol, the booster being cordite-filled. Configuration is shown by a sketch.

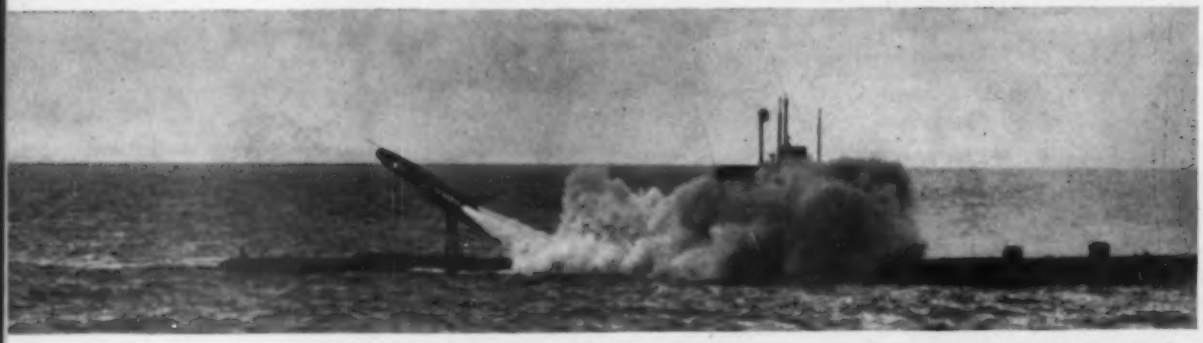
Sud-Est 4300. The design of this weapon seems a remarkable achievement. Intended to be operational at all heights up to 65,000ft,

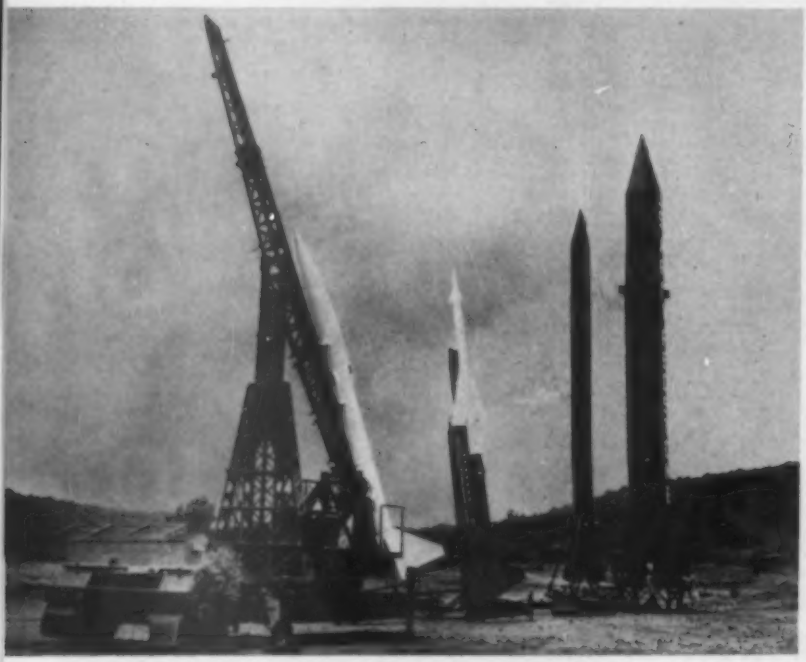
Guided Missiles 1956 . . .

Most of France's missile testing is done in North Africa. Here, at Colomb-Bechar, in the Sahara, a PARCA anti-aircraft weapon (page 907) is launched by rocket boost.

A menacing aspect of the mighty Northrop SM-62 Snark intercontinental cruise missile, immediately after take-off.

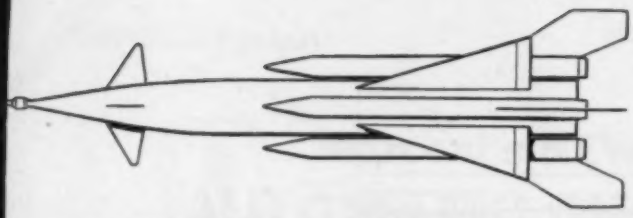
Chance-Vought's Regulus can be carried by, and launched from, two submarines of the U.S. Navy. A Regulus 1 is pictured below being launched from U.S.S. "Tunny."





Oerlikon Type 54 anti-aircraft missiles on their twin launcher.

Four giants of the U.S. Army missile arsenal: from left to right, Honest John, Nike Ajax, Corporal and Redstone (Jupiter A).



Parca. SAM with liquid-propellant sustainer and four wrap-round, solid-propellant boost motors. Length overall (as shown), about 16ft 6in; span, 5ft 3in; body diameter, 21in; weight complete, 2,200 lb; burn-out speed, M=1.7; ceiling, 65,000ft+

it is a two-stage SAM, with a solid-propellant booster and an internal sustainer rocket. Design Mach number is 2. The unusual factor is that it has a span of no less than 11ft 1in, and weighs 2,200 lb.

AIR-TO-SURFACE

Ouest Aviation. At the end of September the company announced that they had "been carrying out for several years, under our own initiative . . . the preparation of a long-range ground-to-air missile which will be the ultimate development of the Trident (a piloted fighter). The first derived version of this aircraft, entirely guided, will shortly be put into flight."

Nord 5200. Originally designated S.F.E.C.M.A.S. SS.10, this crude but effective weapon was first revealed in May 1953. Derived largely from German work, it has command guidance transmitted through thin wires unwound from bobbins carried in the missile. It is designed for use against armour, and has a 6.7 lb shaped charge in the warhead.

It can be launched from aircraft or by a foot-soldier, and in the latter case the ingenious storage container also forms the launcher. The twin-wire control cannot be jammed and 80 per cent accuracy is claimed at one mile range, the missile spinning slowly for stability. It has been launched from the Flamant, Storch, Alouette and Djinn, and in 1950 was evaluated by the U.S. Army.

Nord 5210. Developed from the 5200, this anti-A.F.V. weapon has improved guidance and greater range. It is in production and will shortly become the first French operational missile.

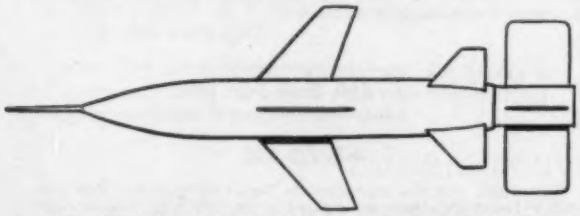
Sud-Est 1522. In active design status since 1955, this weapon is completely "under wraps" at present. It is stated that a probable offshoot will be an AAM.

SURFACE-TO-SURFACE

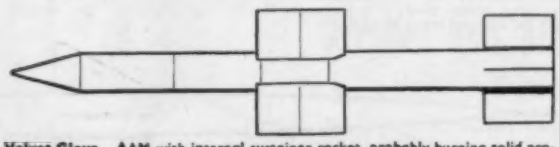
DEFA/ENTAC. Developed by the government armament establishment for use by forward troops against armour, this missile is more refined than the Nord 5210. It nevertheless retains cable guidance; propulsion is by a smokeless, solid-propellant rocket, and the maximum operational range is 2 km (about 1¼ miles).

Ouest-Aviation. Two months ago this large aircraft company stated that they were engaged in the development of "various types of strategic missile with a completely new navigation system."

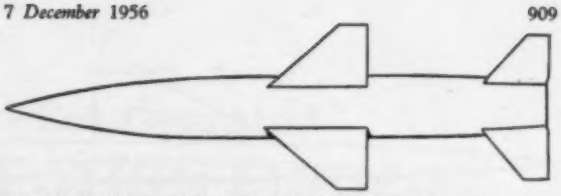
Sud-Est 4200. Owing to its easy design parameters and general "1945-type" outlook this subsonic SSM is almost ready for service, should it be adopted. It has an aircraft-type configuration, with no horizontal tail and vertical fins on the wing tips. Zero-length launching is effected with two or four solid boost motors (two below and sometimes two more above) and cruise propulsion is provided by an integral ramjet. Range can be extended by a droppable tank, as shown in the drawing. Guidance is by radar command.



Sud-Est 4100. SAM with solid-propellant sustainer and solid-propellant boost motor. Overall length, with boost motor, about 9ft; span, about 3ft 2in; body diameter, 12in; weight, with boost motor, 287 lb; burn-out speed, about M=1.2.



Velvet Glove. AAM with internal sustainer rocket, probably burning solid propellant. Overall length, at least 10ft; span about 3ft 6in; weight, at least 500 lb.



Matra M.04. SAM two-thirds-scale model, with liquid-propellant motor rated at 2,730 lb for 14 sec. Length, 15ft 1in; span, 5ft 10in; body diameter, 16in; weight, from 770 to 1,012 lb, usually nearer the latter; burn-out speed, 1,100 m.p.h.

Nord 5103. AAM with two-stage solid-propellant motor. Overall length, 8ft 2½in; span, 3ft 2in; body diameter, 11in; weight, 287 lb; burn-out speed, M=1; range, 4 to 7 miles.

Veronique. Developed at the Vernon Laboratory since 1949, this ballistic weapon was originally employed in general research. A unique feature is that it is tethered to the launcher by four wires, each attached to cross-fins; as the missile ascends, the wires unwind uniformly from a profiled drum (protected from the rocket blast by a deflector) to hold the flight truly vertical, the fins finally being blown off by clockwork-triggered charges.

Looking like any other such missile, Veronique is 19.68ft long, 21.6in in diameter and is propelled by an RFNA/petrol motor giving 8,800 lb for 35 sec. With a launching weight of 2,205 lb speed is 3,100 m.p.h. at a burn-out at 40 miles. In 1953 Diomede Catroux, then Secretary for Air, said that the weapon could carry "a military load" for 150 miles, and that a longer-range SSM was being evolved from it.

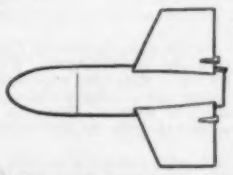
CANADA

AIR-TO-AIR

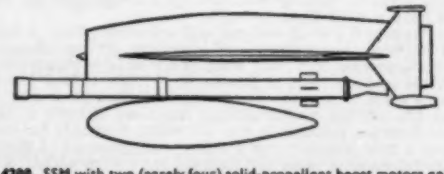
Velvet Glove. In April 1952 Dr. O. M. Solandt, chairman of the Defense Research Board, announced that an air-to-air missile was being developed by the Canadian Armament Research and Development Establishment, at Valcartier, P.Q. In August of the following year it was stated to have reached the flight-test stage; an F-86 Sabre was being used, although the missile was intended for use on the CF-100 all-weather fighter.

In appearance this Canadian weapon is utterly simple and straightforward. Although several varieties have been made, most are as depicted in the drawing below. It is very large for an AAM of such early conception, and the size of wings and controls may indicate that good altitude performance was a requirement. The body is made from wrapped sheet. A curious feature is the small recess cut fom each wing root.

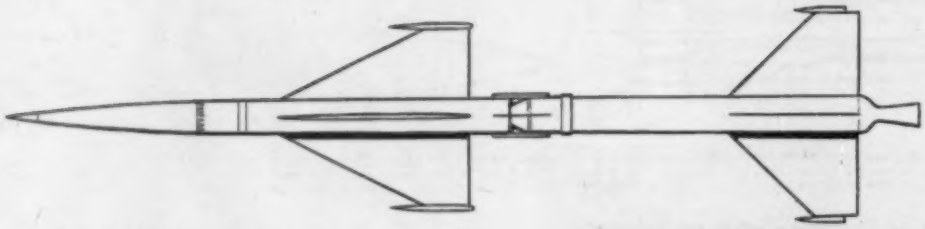
Development was reasonably happy, but early this year the programme was cancelled owing to insufficient range, according to an American report. Velvet Glove, as the weapon was known, was largely engineered, to C.A.R.D.E. requirements, by Canadair. In 1955 the



Nord 5200. SSM with solid-propellant motor. Length, about 3ft; span, about 2ft 6in; body diameter, 7in; weight, 31-35 lb; burn-out speed, rather more than 200 m.p.h.; maximum range, 2 miles.



Sud-Est 4200. SSM with two (rarely four) solid-propellant boost motors and single integral ramjet. Length, 6ft 2in; span, about 9ft 6in; body external diameter, 1ft 5in; weight, about 300 lb; cruise speed, M=0.9; range, up to 62 miles.



Swedish SAM. Anti-aircraft missile with solid-propellant tandem boost motor and liquid-propellant sustainer. Length, with boost motor, about 25ft; weight, with boost motor, about 1,500 lb; burn-out speed, about M=2.

Guided Missiles 1956 . . .

(Canada—continued)

company stated "we have produced missile airframes and control equipment . . . have seen them through their actual firing trials." On August 24 (p. 298) we published a striking photograph of a CF-100 armed with a quartet of Velvet Gloves carried on under-wing shoe launchers. The Canadian Defense Minister recently gave the total Velvet Glove bill as £8.5m. Nevertheless, its use in providing practical experience for the 400 designers who worked on it will be invaluable, and will ease the problems of licence-producing Sparrow (p. 899).

SWEDEN

Guided-missile development is being carried out in a well-organized manner, with very complete integration with the armed forces. Weapons are being evolved in seven classes, all under direct government contract for the Royal Swedish Air Force, Army or Navy. The classes are: air defence; air-force attack; air-to-air; two types for use against naval targets; an anti-aircraft weapon (by Bofors) launched from a submerged submarine; and an army anti-tank weapon.

The guided-missile bureau of the Swedish Defence Board has been fully established since 1953. Appropriations in recent years have been: 1955-6, £250,000 for research and development and £430,000 for production; 1956-7, £321,000 for research and development and £571,000 for production. Principal contractors are Saab and Bofors, A.B., both working as systems managers.

Surface-to-Air. The weapon illustrated is the only one about which any details are known. Developed by several agencies since 1953, it is a two-stage missile "intended for the interception of supersonic aircraft."

The missile has a liquid-propellant sustainer, large delta wings with streamlined aerials and flare containers on the tips and movable trailing-edge controls. A tandem, solid-propellant boost motor is used.

SWITZERLAND

SURFACE-TO-AIR

Oerlikon Type 54. For at least five years the famous Armament Division of the Oerlikon Machine Tool Works, Bührle and Co., of Zurich, have been almost unique in having developed guided weapons largely on a private-enterprise basis. Today they are able to offer a fully developed and Service-proven surface-to-air missile system for sale "over the counter."

Three years ago a weapon with trapezoidal fins was evolved, with a liquid-propellant motor (no boost motor). Weighing 545 lb, and measuring 16ft long, 4ft 3in in wing span and 14½in in body diameter, the missile was a beam-rider with a speed of 852 m.p.h. and a maximum operating height reported as 66,000ft. Early in 1954 the U.S.A.F. bought 25 of these weapons and, as the MX-1868, evaluated them at Holloman.

The present Type 54 is large and more refined. Like its predecessor it has a body made from wrapped light-alloy sheet with Araldite bonding, the wings being of sandwich construction. The wings, which are now of delta form, are arranged to slide axially to compensate for changes in c.g. and c.p. during flight; control is effected by a tail cruciform, and at low speeds by the swivelling combustion chamber. Fuel is diesel oil, mixed with RFNA (nitric acid) with ignition by a hypergolic spray of xylidine and tri-ethyl amine; feed is by nitrogen pressure from a 4,267 lb/sq in bottle.

The ogive nose is a 44-lb warhead with a proximity fuse. Launching, without any boost, is possible at any angle from 90 deg down to about 30. After gathering in a wide beam the missile is centred in a fine pencil beam (see our issue of January 7, 1955 for system details) and describes a curve of pursuit. Motor burn-out takes place after 30 sec, at Mach 1.8, and the combat altitude limits are 10,000ft to 50,000ft. Range with certain guidance is 9 to 12½ miles. Normally the missile is fired from a twin launcher, and a battery comprises six of these, each with a target-tracking radar and coupled beam transmitter. All units are mobile and the sustained battery rate of fire can reach 12 rounds per minute. Training rounds are arranged to break in half just ahead of the wings, each portion being recovered by parachute.

U.S.S.R.

As one must expect, there is at present very little reliable information on current Russian guided-weapon activity. The following notes are virtually all that can be gleaned without straying into the world of fantasy.

Air-to-Air. At Kubinka airfield earlier this year several types of aircraft, presumably machines like the Mig-17, were seen to be equipped with launching shoes suitable for AAMs. One such shoe was fitted beneath each wing.

Surface-to-Air. In the summer of 1955 production of this type of missile was estimated by the Pentagon at "2,000 per month." Five months ago Gen. Earle Partridge, commanding U.S.A.F. Continental Air Defense Command, and Sen. Symington, chairman of the Senate sub-committee on U.S. airpower, stated that the U.S.A.F. "has photographs" of SAM batteries "in the Moscow area." Gen. Partridge said that the missiles were "like Nike or Talos."

Surface-to-Surface. The following is a diary of "beliefs and announcements":

November 1954, U.S. Congress: belief that there is a weapon of "twice V-2 range, operationally reliable" and that research work is aimed at 1,500 miles.

April 1955, Gen. Benjamin W. Chidlaw, U.S.A.F. (then commander of C.A.D.C.): "within 10 years . . . an IBM . . . Mach 10 to 20 . . . any target in the U.S. in 30 minutes or so. Closer is an IBM . . . of Mach 2 to 3."

December 1955, Premier Bulganin: "the Soviets have developed an intercontinental missile . . ." Senator Symington: "the Russians have test-fired a long-range ballistic missile hundreds of miles further than anything this country has attempted . . ." Another senator: "Russia is working at the highest priority on weapons even more fantastic than the ICBM."

Early 1956, Senator Jackson, chairman of the military applications sub-committee on atomic energy: "the Soviets may win the race for the IRBM . . . they may fire a 1,500-mile ballistic missile before the end of this year." It was announced by the Defense Department that ballistic missiles had been fired "with increasing frequency since the fall of 1955" and that a missile with a range of 900 miles had been tested in November of that year.

April 1956, Party secretary Nikita Kruschev: "I am quite sure that we will have a guided missile with a hydrogen-bomb warhead that can fall anywhere in the world . . . so you think we are behind you!"

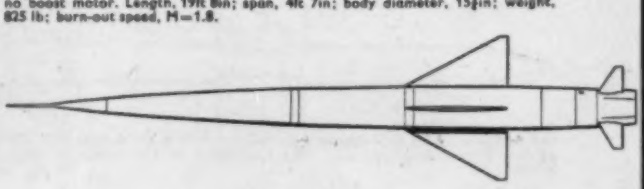
Summer of 1956, Gen. Thomas D. White, U.S.A.F. vice-chief of staff: "Russia could have large numbers of nuclear-tipped ICBMs by 1960." Trevor Gardner, former assistant Air Force secretary for research and development: ". . . have in being an IRBM capable of 700 to 800 miles." Lt-Gen. James M. Gavin, Army chief of research and development: ". . . fired what must have been a rocket for several hundreds of miles in some numbers."

JAPAN

AIR-TO-AIR

Mitsubishi. It was announced in Tokyo recently that Shin Mitsubishi Heavy Industries are engaged in the development of an AAM "production of which will start in 1957." The rocket motor is being developed by Fuji Precision Industries and the guidance is in the hands of the Mitsubishi Electrical Co.

Oerlikon Type 54. SAM with 2,200 lb-thrust liquid-propellant sustainer motor; no boost motor. Length, 19ft 8in; span, 4ft 7in; body diameter, 15½in; weight, 825 lb; burn-out speed, M=1.8.



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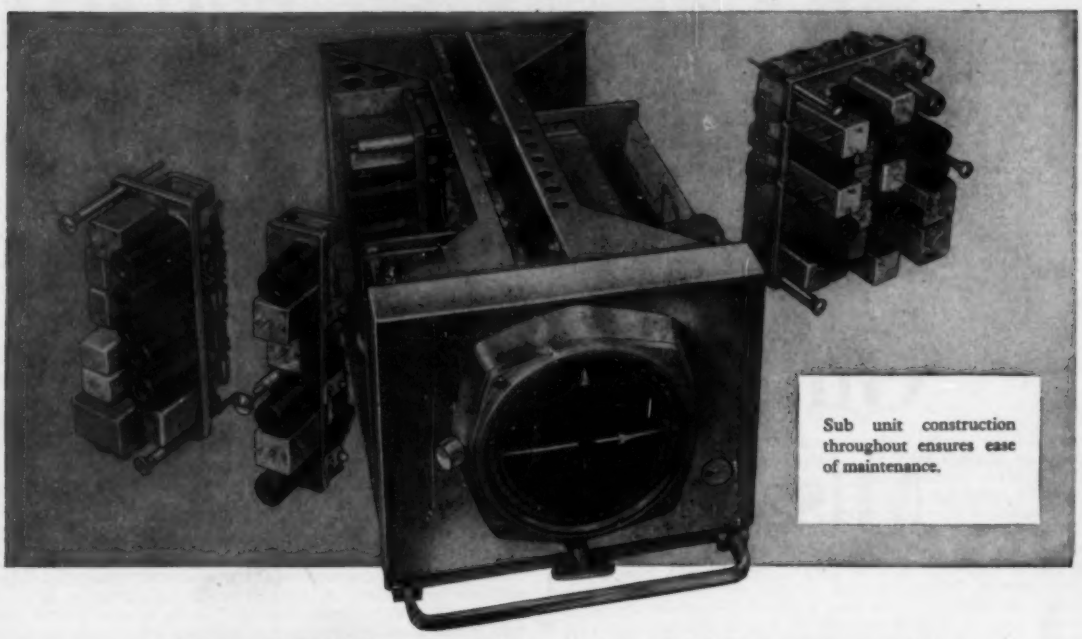

Sub unit construction throughout ensures ease of maintenance.

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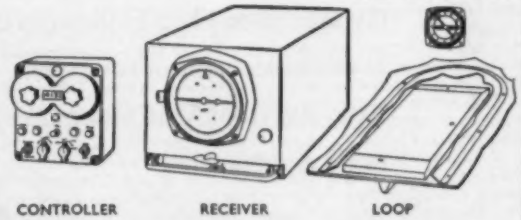
More than forty Airlines and twenty Air Forces fit Marconi air radio equipment. Marconi airport installations are in use throughout the world.

The entire system comprises Controller, Receiver, Loop, QE Corrector, one or more Bearing Indicators and a Sense Aerial.



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electronics and Guided Missiles

"The nine-year silence on Britain's guided missile programme was broken for a brief period when the Royal Aircraft Establishment's guided weapons range at Aberporth was opened to the Press on 24th October. This visit confirmed the view, already widely publicized in the U.S.A., that research and development in this vital field has now reached the stage when it is about 60 per cent. electronics and 40 per cent. aerodynamics."

BRITISH COMMUNICATIONS AND ELECTRONICS
December 1956

Electronic equipment, developed and produced by Ekco Electronics, plays an important part in the Fairey Fireflash, first British air-to-air guided weapon to destroy a radio-controlled target aircraft.
This contribution is typical of
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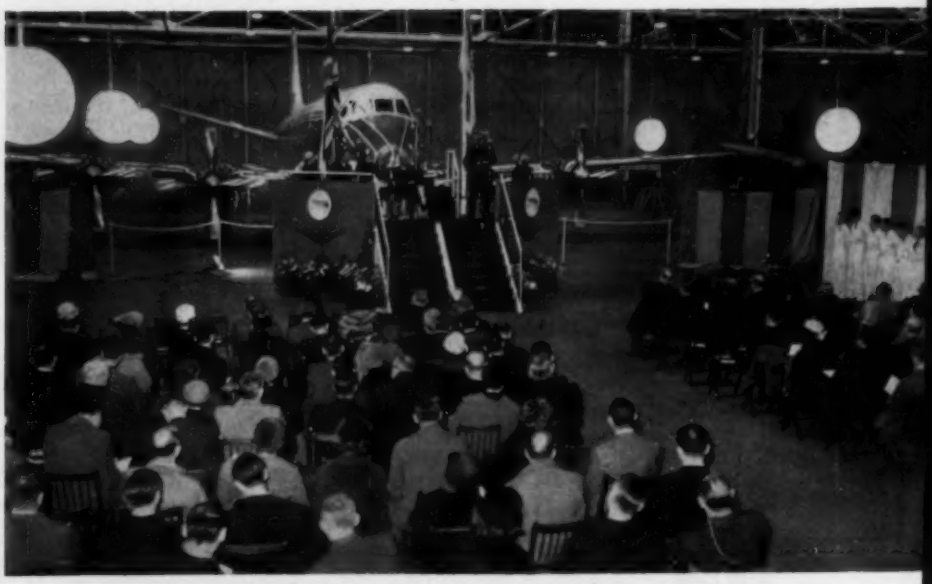
CIVIL AVIATION



B.E.A.'s first Viscount 802 is here seen wearing a false nose for the ceremony held in its honour at Wisley on Tuesday of last week. Lady Douglas baptized the aircraft "Sir Samuel White Baker" in the presence of a large gathering of guests, including Lord and Lady Hives. Deliveries of the first of B.E.A.'s 24 802s will start this month, ready for service early in the New Year. "Flight" photograph

THE INDEPENDENTS DINE

THERE was no gathering of crumbs from beneath Corporation tables at the annual dinner of the British Independent Air Transport Association at the Hyde Park Hotel on Monday of last week. This, by tradition, was the independents' occasion-of-the-year, when all manner and rank of Britain's private enterprise airlines commingled to take stock of the past and to look forward (somewhat wryly) to the future. First and foremost it was a very sociable gathering. Secondly, it was the occasion for the chairman, Mr. G. H. Freeman, managing director of Transair, to ventilate strong views about the lot of the British independents. That these views were aired in the presence of a representative of one of Her Majesty's Ministers (Mr. Watkinson, because of a severe cold, was represented by his Parliamentary secretary, Mr. J. D. Profumo), was no abuse of the precepts of hospitality. Such plain speaking is, indeed, a traditional part of the occasion.

The chairman's remarks were of course given particular point this year because of the magnificent way the independents have risen to the national emergency. They were able, despite their peak summer traffic demands, to respond with capacity to meet the Government's needs during the late summer; and they have with few exceptions given generously of their services to those organizations engaged in the work of Hungarian relief.

"The great expansion of air traffic," Mr. Freeman said, "leaves wide open a gap which the independents can fill," and he disagreed that this could only be done to the detriment of the Corporations. "Look abroad," he said, "at the French independents. These have gone from strength to strength, and now we see U.A.T. . placing a £15m. order for DC-8s."

Mr. Profumo paid tribute to the response of the independents to the Middle East crisis; "there were," he said, "no less than nine companies co-operating at one time." But Mr. Profumo's replies to Mr. Freeman's political points were indirect. "It would," he said, "be wholly wrong to throw the industry into the cockpit of party politics. It is best to continue with what the Corporations and the independents can best contribute in their own ways."

The health of the guests was proposed by Mr. T. W. Morton, vice chairman of B.I.A.T.A. The reply was by Lord Terrington; and it may be said that if his wit is as great at meetings of the Air Transport Advisory Council (of which he is chairman), the deliberations of that august body cannot be as acrimonious as we are led to imagine.

CHANGES IN U.K. AIRWAYS SYSTEM

CHANGES in the United Kingdom airways system have, as expected, now been proposed by the Ministry of Transport and Civil Aviation. They will be explained at a conference to be held on December 14 at the Ministry. The Civil organizations concerned are the International Air Transport Association, the British Independent Air Transport Association, the Royal Aero Club, and the British Gliding Association.

There are at present six airways into London and another connecting London, via the Midlands, with Manchester; and although no details of the proposed changes are given, it is presumed that the upper height limit of these airways will be raised from the present 11,000ft to a height more appropriate to turbine aircraft.

COLLISION IN THE LORDS

PARLIAMENTARY business in the House of Lords on November 28 included a motion by Lord Ogmore on aircraft collisions. The number of near-misses reported in the last two years, he said, was 324; he could cite an occasion when an aircraft in which *he* had been flying experienced two such incidents in one flight.

"May I ask," continued Lord Ogmore, "whether it is possible, by international agreement, to limit for a term of years the cruising speed of civil aviation to, say, 500 miles an hour?" In reply to this suggestion the Earl of Swinton said that "attractive as the idea appears on the face of it, I do not believe that we can limit the speed of an aircraft. When a company is looking at its balance sheet and sees that it has an aircraft that will do 500 or 550 m.p.h. it is comfortable to find that a nice 'stop' order has been placed on future developments of speed, and that the aircraft will have a good competitive working life of seven or eight years. But . . . you cannot stop scientific and technical development in an arbitrary way and . . . you cannot separate, or you can separate to only a very small degree, the development of the great bomber and the great airliner."

MR. FIVE BY FIVE BY SLICKS

REGULATIONS restricting all-cargo operators to the carriage of freight only are necessarily very strict. The principle is quite simple: passengers fly in passenger aircraft, freight goes by air-freighter. But what of the terrible exception, the man who is *too big to squeeze through the passenger airliner's door*? When, indeed, is a passenger a passenger, and when is he freight?

Last week Slick Airways, the American all-cargo carriers, were awarded a permit by the Civil Aeronautics Board to carry "five feet wide" Mr. Robert Earl Hughes from Illinois to New York. Mr. Hughes, who was to appear on a television show, is a man of impressive proportions. He is six feet one inch tall, has a waist line of nine feet seven inches, and weighs 74 stone five pounds.

We do not intend to comment upon this precedent (except perhaps to congratulate Slick upon the diversity of their business); but C.A.B. should, we advise, avoid too free a distribution of such permits to uplift 74-stone men.

Speculation about the possibility of an order for the Britannia from Northeast Airlines of New York ("Flight," October 12, p. 625) was sharpened again last week when Miss Jacqueline Cochrane, a director of the company, flew a production Series 100 from London to Paris and back on Wednesday, November 28. Miss Cochrane, who has 12,000 hours in her log book and is here seen adding to them in the Britannia, said that Northeast "were 75 per cent certain" to buy five aircraft with an option on two more, to serve the New York-Miami route.

CIVIL AVIATION . . .

NEW ARGENTINE AIRLINE

TO develop commercial air services between major cities in the Argentine, a new joint Argentine and U.S. company—Transcontinental Sociedad Anonima—has been formed in Argentina. The U.S. interest—amounting to 25 per cent of the initial share capital of 40m pesos—is held by Californian Eastern Aviation, who, initially at least, will handle the technical side of the business. This will include the management of all the flying operations and the supply of five Super Constellations.

The new company, headed by Senor Manuel Masllorens, has carried out what is claimed to be a comprehensive study of business prospects, from which it concludes that, after an initial loss, it should reach the break-even point before the end of 1959.

International services covering flights between Buenos Aires, Sao Paulo, Rio, Caracas and New York should start in July 1957, using the first three Super Constellations to be delivered. Towards the end of the year, with five aircraft at their disposal, Transcontinental hope to operate between Buenos Aires, Sao Paulo, Lima, Mexico and San Francisco. They may also go to Tokyo and Hong Kong. Domestic services, neighbouring South American countries, Cuba, the U.S.A. and Europe are also served from Buenos Aires by Argentine Airlines, the state corporation.

THE PRIVATE PILOT'S FUTURE

SOONER or later, reasons the private pilot, even if authority does not ring down the curtain finally upon his activities, all flights will be declared to come under I.F.R. control and he will require equipment that he cannot afford and an instrument rating that he cannot easily obtain or readily renew.

These fears are current on both sides of the Atlantic. In the U.S., Mr. James T. Pyle has outlined the Civil Aeronautics Administration's attitude to private flying. The three-year Federal Airways plan, for which Congressional approval has recently been obtained, should provide, said Mr. Pyle, "an adequate service" for both private flyers and operators of larger aircraft. Main feature of the plan is to increase radar coverage. Long-range radar for route control and improved airport surveillance radar with a 30-mile effective radius will be used. Direct controller-pilot communications will be established, and many more navigation aids—from which will eventually emerge the Vortac short-range navigation system—will be introduced. By the end of 1957, it is hoped to control all I.F.R. flight, whether on or off the airways, above 24,000ft and down to 1,500ft. This lower limit will be reduced as facilities improve, and positive control will be extended to V.F.R. as well as I.F.R. flights.

Mr. A. H. Stratford, civil aircraft adviser to the chief designer of Armstrong Whitworth Aircraft. He is building up a small staff at the A.W.A. London office to produce route studies for potential operators of the A.W.A. 650 Freighter/Coach.

An increasing number of V.H.F. omni-directional radio ranges are to be integrated with Tacan equipment to make complete Vortac systems; by 1965 Mr. Pyle estimated that more than 1,200 Vortac systems should be available in the U.S.

"I see no reason," said Mr. Pyle, "why the private pilot will ever have reason to fear such measures. There will always be ample routes and altitudes to take him wherever he wants to go . . . There will be more services for him than ever before." The private pilot, said the C.A.A. administrator, would remain a welcome customer and would get the same standard of service as other users. Certain restrictions might have to be imposed, but they would not cause any particular hardship, and all pilots would derive a net gain from the general improvement in the system.

What will be required of the private pilot who has to operate in the changing pattern of traffic control? "As far as I can see into the future," Mr. Pyle asserted, "there never will be a compulsion to obtain an instrument rating, though I hope . . . more and more pilots [will be sold] on the greater pleasure they can get of flying through such ability. About the only thing a pilot will need to get around freely is two-way radio. . . . Perhaps some inexpensive metal radar reflector will be necessary on fabric aircraft . . . this will require further study."

With radar to track the private pilot, and with two-way radio to enable him to receive and respond to directions, A.T.C. will have adequate control in the altitudes at which light aircraft normally fly. At the higher altitudes used by aircraft two or three times as fast, said Mr. Pyle, the C.A.A. may eventually require the carriage of radar beacon transponders, distance measuring equipment and other devices. "But," he said, "the man who can afford a pressurized aircraft won't worry about this, and the man in the light aircraft won't have to." [*An article on the insidious shouldering-out of the private pilot from the London area appeared in "Flight" of November 23.*]

BREVITIES

THE Syrian Government have excluded aircraft carrying British and French crews from the recently re-opened Syrian airports. Flying outside prescribed corridors in Syria has been prohibited: aircraft must land at Damascus but must avoid other towns or risk being shot down. Photographic apparatus may not be carried in crew or passenger compartments. B.O.A.C. flights to India and the Far East are now routed *via* Turkey and Iraq.

* * *

A Ministry of Civil Aviation team conducted sound-measuring experiments at Gatwick with a helicopter on November 27. It was led by Mr. J. V. Noyes.

* * *

The services of B.O.A.C.'s associate, Arab Airways, have now been resumed on all routes except that to Cairo. They were suspended at the beginning of November.

* * *

Lufthansa's financial report covering April to December 1955, published last week, records that its load factors on the North Atlantic service were 39 per cent (passengers) and 32 per cent (cargo). The average for all carriers was 69 per cent.

"Flight" photograph

Two 16-day Caribbean tours are announced by B.O.A.C. in conjunction with B.W.I.A. Both will be flown by Viscounts.

* * *

An S.A.S. DC-7C has completed a New York to Hamburg non-stop flight in the record time of 9 hr 56 min.

* * *

Peking radio reports that the Peking-Moscow-Prague Tu-104 service was opened in Peking last Sunday. The route is flown once a week in each direction.

* * *

T.W.A., who have recently added a C-82 Packet to their fleet, now operate 173 aircraft. Deliveries of 24 L.1649As will start in April 1957.

* * *

Three experimental runway lighting systems are to be tested by C.A.B. in the next few months. Two of the systems (which differ in their optical characteristics) are of the bar lighting type and the third is a runway edge-lighting system.

* * *

It is announced by the M.T.C.A. that Mr. C. D. Waldron is to succeed Mr. Jeffs (whose appointment as London Airport commandant was announced in *Flight* of November 23) as commandant at Prestwick from January 12.

* * *

A Constellation of Linea Aeropostal Venezolana crashed into a mountain in driving rain on November 28. The aircraft sent a distress signal when 35 miles out of Caracas Airport, but the reason for the signal is not yet known. All 25 people on board lost their lives.

Appraisal of the Vanguard in all three dimensions is now possible in the Vickers mock-up department at Weybridge. A description of the mock-up appeared in our issue of November 9.

Moulding the future . . .

No dog, no vanman, no load—yet. When they come, this B.R.S. van, built by Holmes Ltd. of Preston, will have a hard life. And from road to roof it is ready to take it. The translucent roof especially: it is tough enough to take a poke from a pole or a bang from a box. It is made of Fibreglass Reinforced Plastic, the material that doesn't drum, dent or corrode, that can be moulded to complex shapes in one piece—without high pressures or costly equipment.

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CORRESPONDENCE

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns; the names and addresses of the writers, not for publication in detail, must in all cases accompany letters.

Chipmunk Challenge

TO one who devotes a considerable amount of time and energy trying to arouse enthusiasm for British aviation, the article on Chipmunk Conversion by David Ogilvy (*Flight*, November 16) was disheartening.

There is no need to create difficulties for the flying clubs. The small size of the U.K., the necessity for essential Service flying and the fact that we are the hub of a world network of air routes combine naturally to make private flying all-but impossible.

But in spite of the national desirability of having as big a pool of pilots as possible, one gets the impression that far too many in authority would like to see an end of private flying.

However, there are usually two sides to a question and one assumes that the alterations to the Chipmunk referred to in the article were made with good, if mistaken, intentions. One wonders if the people responsible for the apparently incomprehensible C. of A. alterations would rise to a challenge to explain the motive behind the changes necessitated to make suitable for civilians an aircraft safe enough for the Duke of Edinburgh in Service use?

London, S.E.19. MAURICE ALLWARD.

Denham Accessibility

THE article "London Off-Limits," by H.W., in your issue of November 23, makes a very useful plea on behalf of private pilots wishing to use an aerodrome near London. His suggestion that Hendon be made available to private owners and club aircraft when the R.A.F. move out, would certainly be the answer. But I must protest strongly at his remarks regarding the aerodrome at Denham.

He says "Denham is small, fairly well out and not very accessible except by car, and can offer no hangarage and only limited repairs." I agree that Denham is small, but we are, in fact, quite close; only Elstree is nearer.

As regards accessibility, I would like H.W. to know that in this respect we are extremely well placed. We have trains every half-hour to Marylebone from the station, 15 minutes' walk away, and the journey takes 40 minutes. The nearest bus stop is ten minutes' walk from the aerodrome. Buses to Uxbridge run every 15-20 minutes and from Uxbridge it is possible to reach all parts of London by the Metropolitan railway and Piccadilly line.

The reason there is no hangarage available to visiting pilots (and this is not always so) is because all available space is taken up by club aircraft and private owners.

Denham Flying Club, Bucks. D. C. Y. WRIGHT,
Secretary and Aerodrome Controller.

[H.W. comments:—Mr. Wright's helpful information proves my point. When "the nearest bus stop is ten minutes' walk from the aerodrome" that surely means "not very accessible except by car"; and not even trains to Marylebone every half hour, or frequent buses to Uxbridge, can persuade me that Denham is a "convenient" London airfield—as defined by the context of my article.—Ed.]

IT is quite right for H.W. to press for the use of Hendon as a private pilots' London aerodrome; with the A41 running by it and the Northern Line next door, it forms an excellent departure and arrival point. Too small for most Service or commercial aircraft, it is of ideal size for private machines; and its runways ensure serviceability under conditions which would render grass fields impossible for use.

I understand that the Air Ministry is trying to dispose of many airfields. Let it lessen this number of troubles, and increase the happiness of many private owners, by handing over Hendon to the M.T.C.A. It will be gratefully and frequently used.

London, E.C.4. PAUL JONES.

Warren Merriam

IT was with regret I read in *Flight* for November 23 of the death of my old friend and instructor, F. Warren Merriam. Of all flying instructors up to the end of the first world war, Merriam was quite outstanding in showing patience, humour, understanding and above all in inspiring confidence.

One personal instance of his humour may be of interest. During my instruction, he used to take me over the local cemetery and then tell me to do a series of figure 8s or right- or left-hand circles. I noticed that he did not appear to be in the least worried about my flying and, looking round occasionally (we were flying in a pusher biplane with the instructor in the back seat), I saw that he was gazing placidly at the cemetery. Other instructors of the time would have been agitated about my flying! I imagined that he was testing my nerves and decided that if he was quite happy about my poor turns, I would show him I was not worried; it improved my flying. Years afterwards, when I knew him as a friend on level terms, I questioned him about these tactics.

The answer was quite simple. His wife lived near the cemetery and a figure 8 meant that he would be back for lunch; a right-hand circle meant he would be detained; and a left-hand turn conveyed some other message!

I also had to thank him for sending me up solo after a fatal crash on the aerodrome. I hated it, at the time, particularly as I had to make several attempts to land near the blazing wreckage. Most contemporary instructors would have stopped flying for the day, but he saved my nerve.

Potters Bar, Middx. A. H. CURTIS.

Spotters' Corner

I WAS most interested to see more details of the Lockheed U-2 in print, as I believe I saw this aircraft near Cambridge on May 14 this year. On that occasion, also, the aircraft was in natural finish and seemed to be devoid of any markings. It was flying quite slowly and at about "circuit" height in the area of R.A.F. Waterbeach. The photograph in *Flight* for November 23 corresponds most happily with a rough sketch I made at the time.

Bristol, 7. P. K. A. MORRISH.

NOW that the Lancaster has ended its life the enclosed photograph [unfortunately unsuitable for reproduction.—Ed.] may be of interest. I took it on the scrapheap at R.A.F. Wroughton on October 21. This aircraft is a B.7, RT690, and had been used at Farnborough with a short conical nose-probe; the modified nose could be seen. RT690 was not actually being broken up but was being dismantled for transport to Weedon. It was white overall with black undersurfaces.

Many other Lancaster M.R.3s were on the airfield, and ten in the old white/grey Coastal colours were in the process of being broken up by Hants and Sussex Aviation.

In the Queen's Flight hangar at Benson on Battle of Britain Day was the prototype Heron Series 2 G-AMTS. It was in R.A.F. markings but with Heron in light blue on the white top. The registration letters were in masking tape on the rear fuselage in black, but, from the angle I saw it, it was impossible to see any R.A.F. serial; I gather it is XL961. Also at Benson in the R.N.V.R. Southern Air Division's hangar, was a T.F.5 Firebrand, EK728, in derelict condition.

Maldon, Essex. R. NEWTON.

FORTHCOMING EVENTS

Dec. 3-8. Association Pour L'Encouragement à la Recherche Aéronautique: Exhibition of Rockets, Guided Missiles, and their Equipment, Paris.
Dec. 7. R.Ae.S.: Graduates and Students Section: Film Show.
Dec. 7. Helicopter Association: "Automatic Pilots for Helicopters": Part I, "Theoretical Considerations," by H. Collomosse, B.Sc.; Part II, "Flight Development," by M. C. Curtiss, B.Sc., A.F.R.Ae.S.
Dec. 8. Society of Model Aeronautical Engineers: Annual Dinner and Dance.
Dec. 11. R.Ae.S.: Section Lecture: "Materials for Aircraft Structures Subjected to Kinetic Heating," by Prof. A. J. Murphy, A.F.R.Ae.S.
Dec. 12. Kronfeld Club: "Gliding till Now"; film by Lawrence Wright.
Dec. 19. Kronfeld Club: Christmas Party.
Dec. 20. R.Ae.S.: All-Day Section Lecture on Transonic Wind Tunnel Testing Techniques: Papers by H. F. Vessey, F.R.Ae.S., R. Hills, A.F.R.Ae.S., J. A. Kirk, A.F.R.Ae.S., F. O'Hara, and F. E. Roe, Grad. R.Ae.S.

R.Ae.S. Branch Fixtures (to Dec. 20):—
Dec. 3, *Derby*, "Development and Production of High Temperature Alloys for Turbine Engines," by H. E. Higgett; *Glasgow*, "Supersonic Aircraft and Missiles," by P. J. Duncton. Dec. 5, *Bristol*, "Prospects and Problems in British Aviation," by P. G. Masefield; *Luton*, "Trends in Aircraft Electrical Installations," by H. Zeffert; *Chester*, "Problems Associated with Non-metallic Materials in Aircraft," by N. J. L. Megson and E. W. Russell; *Christchurch*, "Transfer Machining," by A. J. Sephton. Dec. 10, *Henlow*, Student Members' Lectures. Dec. 12, *Leicester*, Annual General Meeting and Film Show; *Christchurch*, "American Production Methods," by J. A. Mackenzie; *Coventry*, Lectures by Junior Members; *Merthyr Tydfil*, Film Show; *Preston*, "Novel Methods of Take-Off and Landing," by T. J. Cummings; *Southampton*, Fourth Mitchell Memorial Lecture, "Noise and Aircraft Structures," by Prof. E. J. Richards. Dec. 13, *Bristol*, Film Show; *Brough*, "Flying Saucers," by D. Leslie; *Cheltenham*, "Accident Investigation," by Lt.-Cdr. F. R. Fenton; *Isle of Wight*, Annual General Meeting and Film Show. Dec. 14, *Weybridge*, Annual Dance. Dec. 20, *Belfast*, Debate.

THE INDUSTRY

The air-driven crash-rescue saw referred to in the adjacent column. Needing no independent power source, it could be used by a man winched-down from a helicopter.

Self-contained Rescue Saw

A PORTABLE crash-rescue circular saw, operated by compressed air, has been developed by the Consolidated Pneumatic Tool Co., Ltd., 232 Dawes Road, London, S.W.6. With a diameter of 12in, and weighing 17 lb, it is driven by compressed air derived from a Siebe-Gorman cylinder pack, weighing 50 lb, worn on the back of the operator.

The "Rippador" Pneumatic Saw, as it is named, is fitted with a sole plate, guard and support handle, and is stated to be capable of cutting "a 2ft 6in square escape hole through fuselage and support members in less than one minute."

The storage cylinders contain sufficient air, at 1,800 lb/sq in, for two minutes' operation of the saw. It is fed through a reducing valve and flexible hose for use at 100 lb/sq in in the vane-type motor of the saw.

A New Radio Compass

A CONTRACT for the supply of a quantity of type AD. 722 sub-miniature radio compasses, to be installed in fighter aircraft now on order for the Indian Air Force, has been awarded by the Indian Government to Marconi's Wireless Telegraph Co., Ltd.

The AD. 722, which has also been selected for three NATO lightweight fighter prototypes and is already in use in the first Fiat G.91, was developed by Marconi's for the R.A.F. to meet the requirement for a radio compass suitable for high-altitude operation and of exceptionally small weight and size. It is designed to operate unpressurized up to 70,000ft, and the complete installation weighs only 22 lb.

The design incorporates new techniques, including the use of a fixed cross-loop aerial which has no moving parts. The loops are moulded in plastic, in a unit only ½in high, which can be mounted outside the aircraft below a shallow housing, thus providing a low-drag installation; while use of a fixed aerial eliminates troubles associated with rotating loops. The goniometer is embodied in the bearing indicator; and the equipment operates entirely on 28 V. D.C., with no internally generated H.T., so avoiding the use of rotary converters.

Hydraulic Test Equipment

VARIOUS types of hydraulic test rigs, both diesel- and electric-powered, and mobile or static, are among the products of the H.M.L. (Engineering), Ltd., aircraft division, 466-490 Edgware Road, London, W.2. Other forms of equipment manufactured by it include brake and tensioning units, and high-speed gear-boxes for driving hydraulic pumps.

Recently the H.M.L. aircraft division issued a handsome and generously illustrated brochure, *HML Hydraulic Test Equipment*, which describes the test rigs in considerable detail and briefly depicts some of the division's other products. One of the photographs shows a mobile hydraulic rig in attendance on a B.O.A.C. Stratocruiser.

IN BRIEF

Mr. Paul D. Irons, B.Com., A.C.A., a director and secretary of Saunders-Roe, Ltd., and also a director of Saunders-Roe (Anglesey), Ltd., and Saro Laminated Wood Products, Ltd., has been elected a member of the Council of the Institute of Chartered Accountants of England and Wales.

* * *

Howard Clayton-Wright, Ltd., Wellesbourne, Warwicks, have issued new illustrated literature containing descriptive data on Clatonrite "Nylastic" adjustable support clips for cable and piping runs. These are available in several types and a wide range of sizes.

* * *

A new F.B.I. handbook, *Applications of Instrumentation and Automatic Control* (Federation of British Industries, 21 Tothill Street, London, S.W.1, price 5s), provides a guide to instruments and controls used in steam-raising and industrial processes, and suggests that in the design of new plant particular attention should be paid to the possibilities of automatic control.

* * *

Courses for business executives on the correct presentation of technical information in clear English are being run by Osmond Turner Mead Associates at 3 Gower Street, London, W.C.1. Lasting ten working days and limited to eight members each, the next courses begin on February 25 and April 29. Information about them can be obtained from Osmond Turner Mead at the above address, or by telephoning Museum 6346.

* * *

Handy Angle, Ltd., Grand Buildings, Trafalgar Square, London, W.C.2, announce two new sections, 2½in × 1½in and 3in × 1½in respectively, in their slotted angle series. The extra width on the narrow flange is claimed to give greater strength and higher loading figures; slot formation is the same on both and they can be used in conjunction with existing slotted angle structures.

* * *

A newly published British Standard, G.153: 1956, specifies requirements for the general and detailed construction of, and accuracy of, air-driven artificial horizons. It has been prepared to provide an up-to-date and separate specification for air-driven instruments, in the light of experience gained in the application of the relevant requirements of B.S. G.110: 1949 (which provides for both air-driven and electrically operated instruments). Copies of B.S. 153, which replaces that part of G.110 relating to air-driven instruments, are obtainable from the B.S.I. Sales Branch, 2 Park Street, London, W.1, price 3s.

* * *

Now visiting the United States is Dr. A. J. Holland, chief physicist of the Triplex Safety Glass Co., Ltd. On December 13 he is to lecture at the Wright Aircraft Development Center on *Curved Glass of High Optical Accuracy for Aircraft Applications.*

* * *

A new factory has been opened by Hanovia (Lamps Division of Engelhard Industries, Ltd.), the manufacturers of Radisil heaters, at their existing works in the Bath Road, Slough, Bucks. This single-storey building, with a floor space of 10,000 sq ft and a total air mass of 100,000 cu ft, is warmed by 80 four-foot 1,500 W Radisil radiant heaters attached to the ceiling.

* * *

The Plessey Group has established an office in Amsterdam—at Singel 160, Amsterdam C—to supervise its interests in Northern and Central Europe. Mr. E. A. Springett has been appointed territory manager and Mr. E. G. Parramore (previously in charge of the Hunter production co-ordination office at The Hague) will advise on the company's aeronautical products as technical consultant.

* * *

A revised edition of their useful book *Machine Tool Lubrication* (first published in 1948) has been issued by Wakefield-Dick Industrial Oils, Ltd. It deals comprehensively with machine tools, covering their construction, operation and lubrication and many other related problems. Complimentary copies may be obtained by members of the industry from P.D. Department, Wakefield-Dick Industrial Oils, Ltd., 67 Grosvenor Street, London, W.1.

* * *

Among the many applications of Cobex rigid vinyl sheeting described in a new illustrated folder, designed to contain data sheets, are its use for internal fittings of passenger aircraft, including the Britannia. It is also approved for Service use for internal fittings, fairings and ductings in aircraft within Class 3 (A.P. 970) category where the working temperature of these components will not exceed 60 deg C. Cobex is a product of BX Plastics, Ltd., Higham Station Avenue, London, E.4.

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Photograph by courtesy of VICKERS-ARMSTRONG LIMITED

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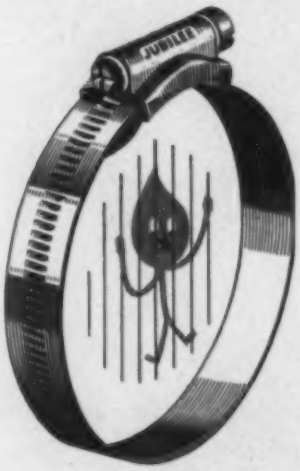

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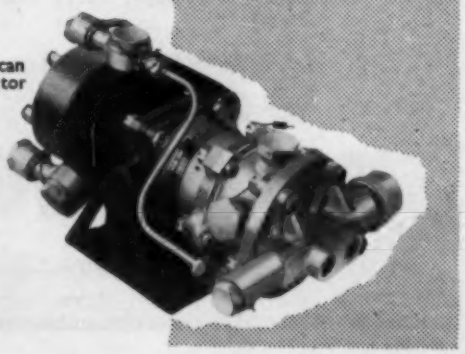

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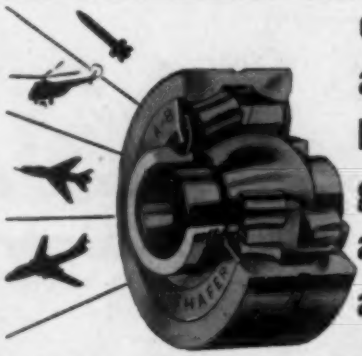

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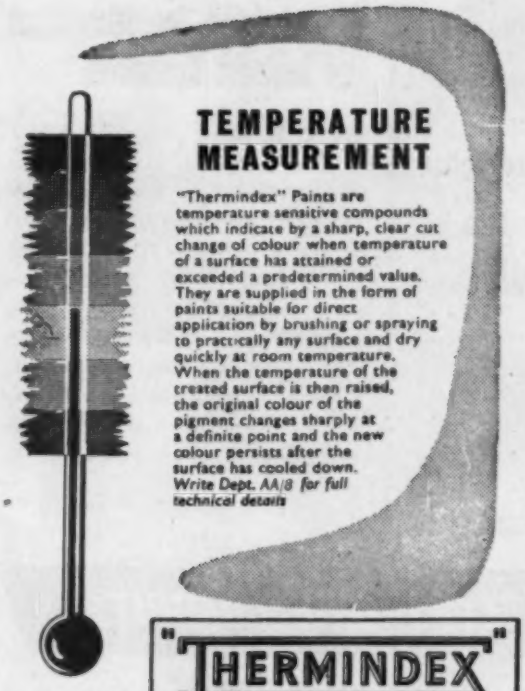

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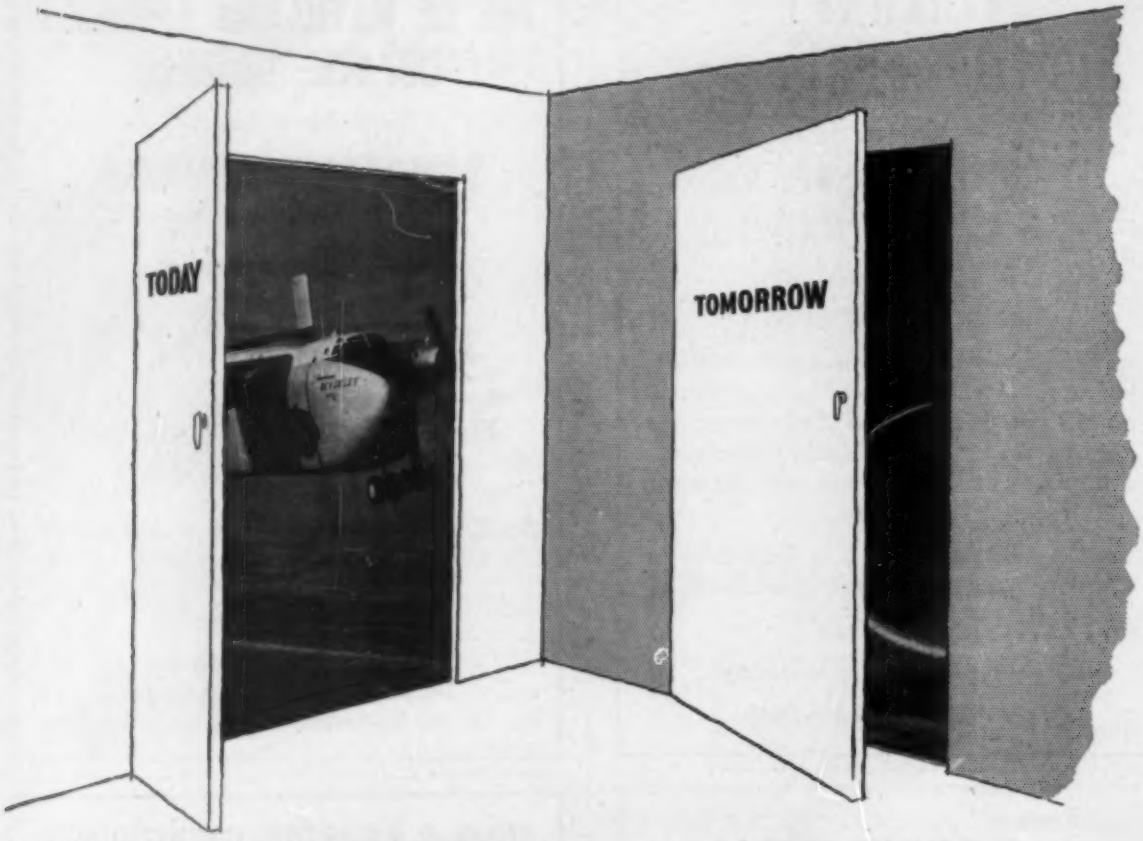

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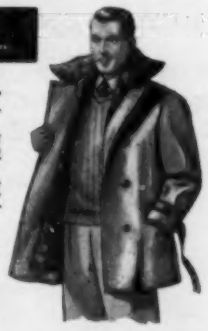

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MODERN CONTACT LENSES CENTRE 7(D.1), Endsleigh Court, W.C.1. Deferred Terms. Booklet sent. [0342

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DEPARTMENT OF SUPPLY

AERONAUTICAL RESEARCH LABORATORIES

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DUTIES: Undertake investigations into the application of statistical methods to problems in aeronautical science, in particular the statistical planning of research and development trials of guided weapons involving the inter-relations of a number of factors.

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Several years of appropriate experience in the application of statistical methods to research or engineering problems will be needed for appointment as Scientific Officer, Grade 3.

THE salaries quoted are in Australian currency.

WHILST the position is temporary, the tenure of employment is not limited.

UNDER specified conditions, first class boat fare (if first class berth available) for the appointee and dependants (wife and dependent children) will be paid by the Commonwealth.

APPLICATION forms obtainable from:

The Senior Representative (AP.73)

Department of Supply,

Australia House,

Strand,

London, W.C.2

WITH whom applications should be lodged by 20th December, 1956. [6004

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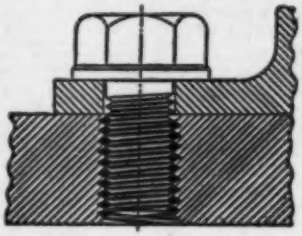

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PUBLIC ANNOUNCEMENTS

AIR TRANSPORT ADVISORY COUNCIL

THE AIR TRANSPORT ADVISORY COUNCIL give notice that they have received the undermentioned applications to operate scheduled air services:—

APPLICATION No. 992. From Skyways Ltd., of 7 Berkeley Street, London, W.1, for a Normal Scheduled Service with Dakota aircraft for the carriage of passengers, supplementary freight and mail between Lympne and Dieppe (Vittefleur) at a frequency of up to six services daily for a period of 10 years, commencing from date of approval.

APPLICATION No. 373/4. From Eagle Aviation Ltd., of Marble Arch House 32-50 Edgware Road, London, W.2, for continued approval to overfly Luxembourg at the Company's discretion for the remaining period of approval on the Normal Scheduled Service which they are authorised to operate during the period up to 31st October, 1961, on the route London (Blackbushe)—Luxembourg-Innsbruck. The Company also ask permission to operate from London Airport as well as from London (Blackbushe).

APPLICATION No. 18/5. From Hunting-Clan Air Transport Ltd., of London Airport, Hounslow, Middlesex, for an amendment to the terms of approval of their Colonial Coach Service which the Company have been authorised to operate between London and Salisbury (S. Rhodesia) until 31st March, 1957, so as to extend the period of operation from 1st April, 1957, to 31st March, 1958, and continue to operate the service at a frequency of three return flights per 28 days from April 1957 to March 1958 inclusive, and for one additional return flight each 28 days for the period April to October 1957 inclusive.

APPLICATION No. 43/6. From Airwork Ltd., of 35 Piccadilly, London, W.1, for an amendment to the terms of approval of the Colonial Coach Service between London and Salisbury (S. Rhodesia) similar in all respects to

APPLICATION No. 18/5 from Hunting-Clan Air Transport Ltd.

THESE applications will be considered by the Council under the Terms of Reference issued to them by the Minister of Civil Aviation on 30th July, 1952. Any representations or objections with regard to these applications must be made in writing stating the reasons and must reach the Council within 14 days of the date of this advertisement, addressed to the Secretary, Air Transport Advisory Council, 3 Dean's Yard, London, S.W.1, from whom further details of the application may be obtained. When an objection is made to an application by another air transport company on the grounds that they are applying to operate the route or part of route in question, their application, if not already submitted to the Council, should reach them within the period allowed for the making of representations or objections. [6006

SITUATIONS VACANT

FEDERATION OF RHODESIA

AND NYASALAND

Vacancy:

SENIOR TELECOMMUNICATIONS OFFICER

(Engineering, Planning and Development)

DEPARTMENT OF CIVIL AVIATION

QUALIFICATIONS: 1. Applicants should hold a degree in Electrical Engineering and/or be Corporate Members of the Institution of Electrical Engineers.

2. Applications will also be considered from candidates not professionally qualified, but who have had substantial appropriate experience.

STARTING Salary £1,650 p.a. on scale £1,650 x 75-£1,800 p.a. for professional candidates; £1,530 p.a. on scale £1,530 x 50-£1,730 p.a. for non-professional candidates.

TRAINING: Preference will be given to candidates who have served a recognised post-graduate or "sandwich course" engineering apprenticeship in the works and test-rooms of manufacturers of electrical and/or telecommunications equipment.

EXPERIENCE: Candidates should have had not less than five years experience, after professional training, in the application of M.F., H.F. and V.H.F. radio-communications systems, including at least two years in the field of Civil Aeronautical Telecommunications, preferably on engineering and planning development including modern navigational aids. Administrative experience is advantageous.

APPLICATION forms and further details from the Public Service Attaché, Rhodesia House, 492 Strand, London, W.C.2. Closing date December 22nd. [6013

PILOT and Navigator required for Air Survey company for senior positions. Write, giving full particulars, to B.K.S. Air Survey Limited, Old Station Approach, Leatherhead, Surrey. [6014

SITUATIONS VACANT

A FINE OPPORTUNITY

For Men and Women

GRADUATES in either Mechanical Engineering or Mathematics. A Midland Aero Engine Firm has vacancies in their Performance Analysis Department on work concerned with the prediction of performance on experimental gas turbine aero engines. Previous experience in this subject is not essential although this would be taken into consideration when fixing initial salary, as also would age and qualifications. Initial salaries lie in the range £700/£900 per annum.

Applicants holding mathematical degrees must have a bias towards Mechanical Engineering. The positions hold excellent prospects, are pensionable and permanent. Applications should be sent to Box No. 5541, quoting reference "Opportunity." Full details of age, qualifications, and experience should be included, and all correspondence will be treated as confidential. [599€

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Interesting and progressive positions are available in our Technical Publications Department concerned with a new and long-term aircraft for personnel experienced in the compilation of technical manuals to M.O.S. and civil standards.

The vacancies include:

1. Technical authors for mechanical, electrical and instrument installations.
2. Technical authors conversant with Pilots' Notes, Repair Schemes and Servicing Schedules.
3. Technical illustrators for perspective line and half-tone work, and electrical routing charts.
4. Technical clerks for Spares Scheduling.

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Apply, giving a brief résumé of experience, to:

The Technical Staff Manager
Blackburn & General Aircraft, Ltd.
Brough, E. Yorkshire

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AERODYNAMICISTS
STRESS ENGINEERS
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We can offer pleasant working conditions, salaries commensurate with ability, and assistance with accommodation for candidates selected to work at Osborne.

★ Those interested should apply, quoting age, experience, qualifications and *ref.* F/10 to the Personnel Officer, Saunders-Roe Ltd., East Cowes, I.o.W.

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APPLICANTS should be between 24 and 30 years of age, have no National Service commitments, hold an honours degree in Mechanical Engineering and preferably have some design experience, although this last is not essential.

THE office is situated in an entirely new building at an establishment concerned only with research and development problems. This is located in the country between Coventry and Rugby and is reached by free Company transport. An up-to-date cafeteria is provided and general conditions of work are good.

PROSPECTS depend entirely on the individual and are almost unlimited for a man of real ability.

Attractive initial salaries, which are subject to constant review; the positions are permanent and pensionable and offer long range security as well as a satisfying career.

APPLICATIONS, giving full details of age, qualifications and experience should be sent to the Chief Engineer, Armstrong Siddeley Motors Limited, Parkside, Coventry, quoting reference YD/NP. They will be treated as confidential. [6011

RADIO Engineer. Licensed A and B Radio Engineer urgently required to take over full control of well equipped and A.R.B. approved radio overhaul shop. Interesting and progressive job for right man. Salary according to qualifications. Pension scheme in operation. Apply in confidence to Managing Director, Eagle Aircraft Services Ltd., Blackbushe Airport, Camberley, Surrey. [5989

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METALS DIVISION

A

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ENGINEER

IS required to co-ordinate the work of a number of engineers on the design and development of special purpose plant, services and facilities in connection with work on a Guided Weapon project. Qualifications necessary are a university degree in Engineering or its equivalent and several years practical experience.

THE post affords interesting work in pleasant surroundings at our Summerfield Research Station, Kidderminster, with good salary and conditions of employment including a 5-day week, profit-sharing scheme and a pension fund.

ON joining the Staff married men will receive a contribution towards removal (including travel) expenses, and in aproved cases, financial assistance will be given towards house purchase.

WRITE for Application Form to the Staff Manager, I.C.I. Metals Division, Kynoch Works, Witton, Birmingham 6, quoting SM/2/F. [6007

DEVELOPMENT Engineers and Physicists (Senior and Junior) are required by Louis Newmark, Ltd., for its expanding laboratories at New Addington, Surrey. The work includes the design and development of electro-mechanical devices used in aircraft control systems and covers all stages up to final installation and testing in aircraft. Experience of pressure capsule and servo following equipment an advantage. Applications from suitable ex-R.A.F. technical personnel are welcomed. Pension Scheme. Apply in writing, giving full particulars, to Personnel Officer, Louis Newmark, Ltd., Prefect Works, Purley Way, Croydon. [6018

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Employment conditions are good. Salaries are progressive. Life Assurance and Pension Schemes. Excellent Sports and Welfare facilities.

Applications stating age, qualifications and experience should be addressed to: The Personnel Officer, South Marston Works, nr. Swindon, Wilts.

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THIS vacancy provides an unusual opportunity for a senior stressman to take over an interesting and responsible position. Applicants should have comprehensive stressing experience with good practical and design background.

An honours degree in either mechanical engineering, physics or mathematics an advantage.

Applications in strictest confidence to the Chief Engineer, Armstrong Siddeley Motors Limited, Parkside, Coventry, quoting reference SS. [6010

SENIOR Weight Control Engineers with experience of high performance complex aircraft are required to work in the Osborne and London design offices of Saunders-Roe, Ltd. Conditions are good, and the salary will be commensurate with ability. Assistance with accommodation is available for engineers joining the Osborne design team. Applications, quoting age, experience, qualifications and Ref. F.17, should be addressed to the Personnel Officer, Saunders-Roe, Ltd., East Cowes, Isle of Wight. [5970

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THE AIR REGISTRATION BOARD has a vacancy for an aeroplane performance engineer with a sound knowledge of aerodynamics and flight test experience. The post offers opportunities of contact with all civil aircraft development in this country, and travel abroad.

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APPLICATIONS with full personal and technical details should be sent to The Secretary, Air Registration Board, Chancery House, Chancery Lane, London, W.C.2. [5997

HISPANO-SUIZA'S English associate, British Manufacture and Research Co., Ltd., of Grantham, require Junior Designers. Initiative in design of small mechanical and electrical sub-assemblies for light gunnery and fire control equipment is valued more than specific experience of gunnery equipment design. The company offers excellent welfare facilities and a voluntary pension scheme. Written applications stating age, qualifications, experience and salary required to British M.A.R. Co., Ltd., Grantham, Lincs, quoting Reference AWK/Staff/F. [6015

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GROUND Engineer required Jan. 1st. State full particulars including licences. Bristol and Wessex Club, Bristol Airport. [6005

TEST and Laboratory Engineers required for gyro and electro mechanical instruments. Apply stating age, experience and salary required to S. G. Brown, Ltd., Shakespeare Street, Watford, Herts. [0147

SENIOR Design Draughtsmen, men with considerable experience in the aircraft industry, are offered the opportunity of joining an organization engaged on work of great interest and importance.

THE successful applicants will be men capable of preparing schemes and controlling the work of a small group. They will be offered good salaries, scope for promotion, reasonable conditions and will work in an excellent office in London. They will be expected to work hard.

THOSE interested should forward relevant details, including present salary, to Section F.20, Box 5566. [5999

ENGINEERS interested in combustion problems associated with gas turbine aero engines of the future are required by Armstrong Siddeley Motors Ltd., Coventry.

Applicants must hold either a degree or H.N.C. in Mechanical Engineering, and previous experience in this class of research, whilst not essential, will be an advantage. Comparative salaries will be paid based on age, qualifications and experience. Positions hold good prospects for right men, together with security for the future.

Applications with full details, to be treated confidentially, should be sent to the Technical Personnel Manager, Armstrong Siddeley Motors Ltd., Parkside, Coventry, quoting refence MS/CD. [6008

DRAUGHTSMEN and Stressmen, with aircraft or G.W. experience, who are keen to work on the more advanced trends in these fields, are required for the London Design Offices of Saunders-Roe, Limited.

THESE opportunities in an expanding office will be particularly attractive to men anxious to obtain positions in a congenial atmosphere with good prospects of advancement.

THOSE interested should apply to the Personnel Officer, Saunders-Roe, Limited, 37 Queen Square, London, W.C.1, quoting ref F.22. [5998

AIR SERVICE TRAINING has a vacancy for a Flying Instructor. Experience as a helicopter pilot would be an advantage. Apply, giving details of qualifications and experience to The Commandant, Air Service Training, Ltd., Hamble, Southampton. [5966

ENGINEERS with A and C Licences on Dakota Aircraft required for various overseas bases including interesting proposition for any engineers considering emigration to Rhodesia. Write Box F 325, L.P.E., 55 St. Martin's Lane, London, W.C.2. [5962

SENIOR Electrical Draughtsmen are required for work on civil aircraft. High commencing and progressive salaries are offered and a generous life assurance and superannuation scheme is in operation. Please send full particulars of experience, etc., to the Personnel Officer, Handley Page (Reading), Ltd., The Aerodrome, Woodley, Reading. [0281

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Aircraft experience desirable but not essential.

The factory is ideally situated in the Cotswolds. Pension scheme, good canteen, welfare and sports facilities. Single accommodation available in Residential Club.

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HAWKER AIRCRAFT LTD., Canbury Park Rd., Kingston-on-Thames, Surrey

D.H. AIRCRAFT

SERVICE DEPARTMENT

D.H. AIRCRAFT

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The Personnel Manager

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Long-Term Programme

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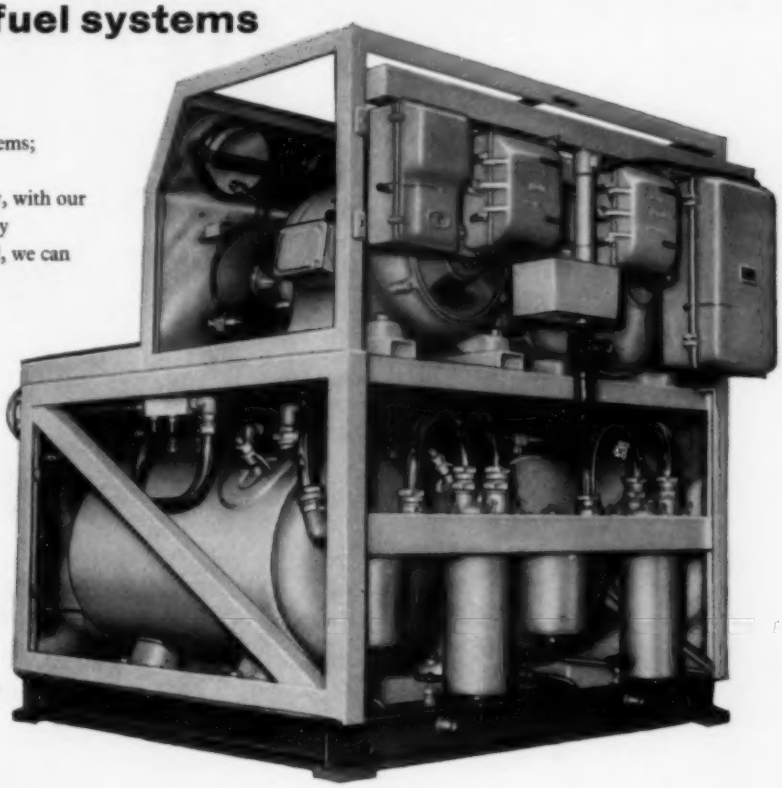

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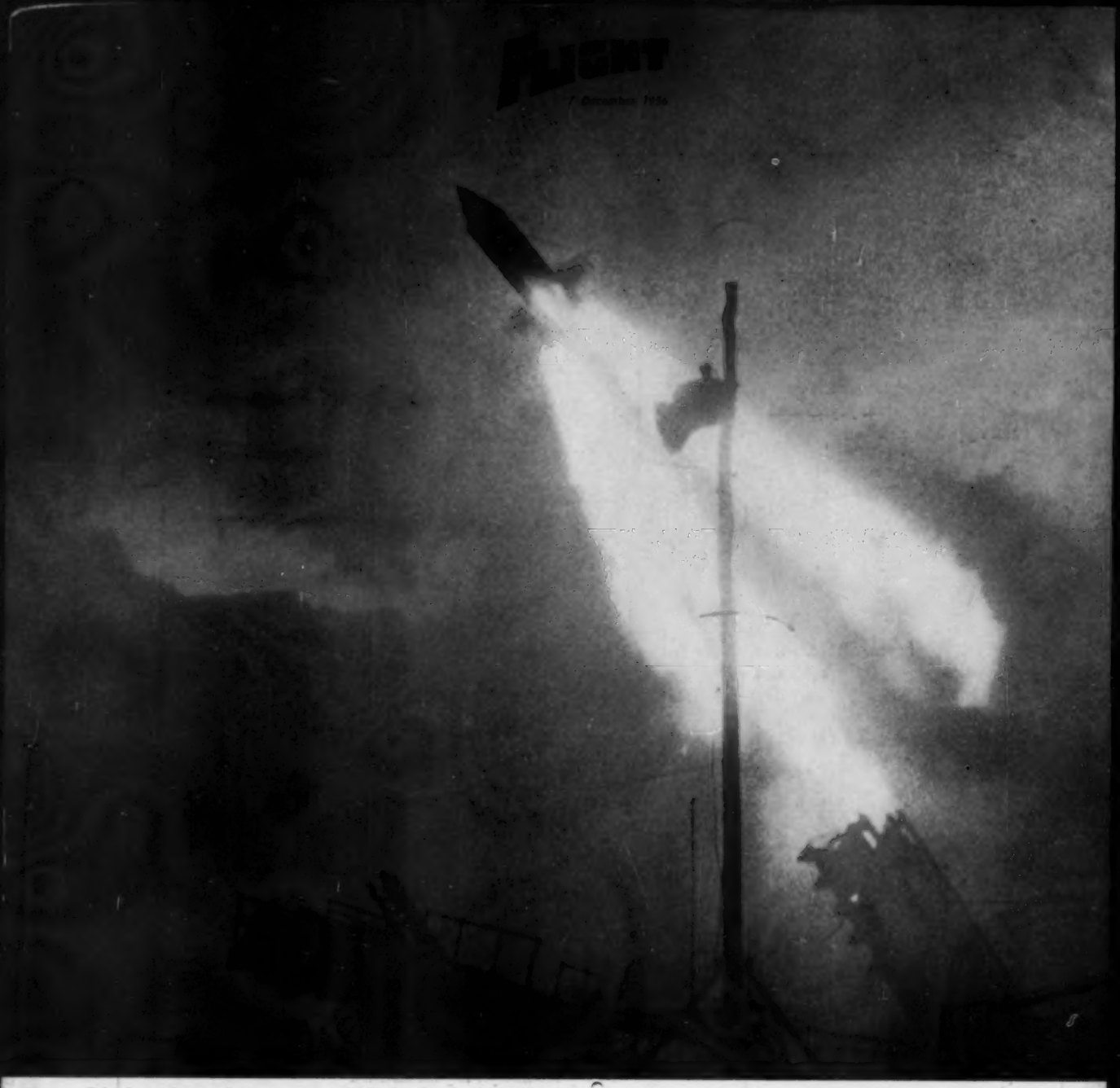

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